

THE SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

VOLUME XXXVI
JANUARY TO JUNE

25800

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NEW YORK
THE SCIENCE PRESS
1933

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THE SCIENCE PRESS PRINTING COMPANY
LANCASTER, PA



HERBERT HOOVER
PRESIDENT OF THE UNITED STATES

THE SCIENTIFIC MONTHLY

JANUARY, 1933

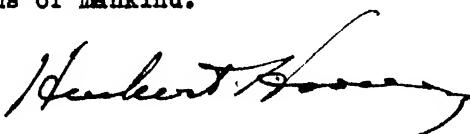
The Scientific Work of the Government of the United States

INTRODUCTION TO A SERIES OF ARTICLES ON THE RESEARCH ACTIVITIES OF THE FEDERAL GOVERNMENT

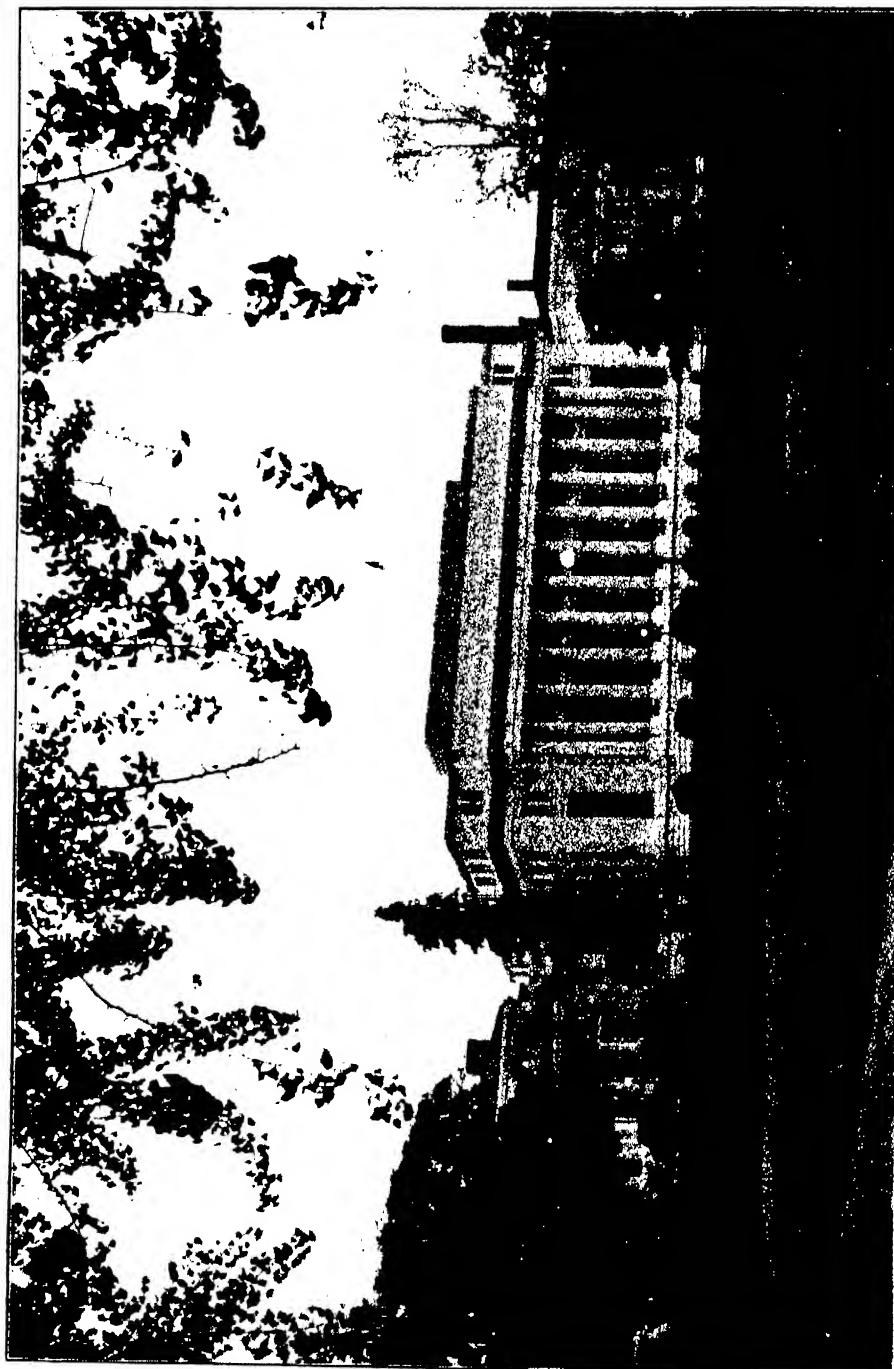
THE WHITE HOUSE
WASHINGTON

The insatiable curiosity of the human mind to probe the mysteries of Nature through scientific research into the operation of natural laws has resulted in such wealth of new inventions and new products, so satisfying to material needs of the people, that the world is irrevocably committed to an eternal quest of further truth, with certainty of endless and ever more rapid change as new knowledge is translated into new conveniences and comforts. The social relations of mankind have already been altered by these changes beyond the utmost imagination of our forefathers. Further and more revolutionary changes will be wrought.

As government is the art of social relations under recognized authorities set up by the will of the people, any change wrought by scientific advance quickly produces new problems of government. The Federal Government itself long ago sensed the potentialities of science when it gave official status to the Smithsonian Institution. From that pioneer body has flowed a stimulation to scientific research of the most valuable character, both directly in its own discoveries and indirectly through its leadership and inspiration of private institutions. Science is also recognized and encouraged by the Federal Government in the researches of the Department of Agriculture in biology, entomology, and other fields; and similarly in other Departments which promote research. Thus the Government still does, and increasingly should, lead the way by example toward the discovery of new knowledge to free mankind from ignorance, superstition, needless fears and poverty. Nor should it be unremarked that a spiritual value accrues in all this labor, for science requires a degree of unselfishness and devotion which calls out the finest qualities of the human spirit, and, since its goal is truth, the noblest aspirations of mankind.



November 28, 1932.



NEW ADMINISTRATION BUILDING OF THE U. S. DEPARTMENT OF AGRICULTURE, COMPLETED IN 1939, WITH THE EAST AND WEST WINGS, COMPLETED IN 1908.

RESEARCH IN THE UNITED STATES DEPARTMENT OF AGRICULTURE

By ARTHUR M. HYDE

SECRETARY OF AGRICULTURE

THE United States Department of Agriculture is an organic whole. It is not a loose bundle of unrelated activities. However unlike one another some of the parts may appear there is a golden thread which binds them together.

Research is not merely the biggest job the department has—it is the foundation of all its other jobs. Research done in this department, coupled with new knowledge from institutions in all parts of the world, figures in everything the department undertakes. One may easily miss this fact in glancing over the list of the department's activities. In annual financial statements, for example, the duties are divided into six general classes: (1) research; (2) extension and information; (3) the eradication or control of plant and animal diseases and pests; (4) service activities, such as weather and crop reporting; (5) the administration of regulatory laws; and (6) road construction. This classification, though convenient for certain purposes, implies that research is only one among many equally important functions. Actually the research is primary. It is the keystone of the structure.

The foregoing classification of functions does not reflect an actual separation of tasks into water-tight compartments. It merely marks boundaries, not so much in the work itself, as in our way of conceiving the work. No sharp line can be drawn, for example, between research and extension. Research results have to be popularly presented before they can be usefully extended. Hence the extension work begins in the research laboratory, which furnishes the necessary educational material in a usable

form. We classify weather and crop reporting as service activities, yet they are very largely research jobs. So is the eradication or control of animal and plant pests. Eradication campaigns would get nowhere without scientific knowledge.

Research bulks large in the administration of regulatory laws. The Food and Drug Law, for instance, forbids the sale of adulterated food and drugs, but it could not be enforced without scientific analyses and standards and research to perfect means of detecting adulteration. Expenditures by the department for road construction cover highway research as well. This research has produced revolutionary improvements in highway design.

In the succeeding articles of this series those in charge of research in the department will describe their projects and problems in some detail. I shall not attempt in any way to anticipate these writers. Something, however, should be said here about the origin and growth of federal research in agricultural science and about the resulting benefits.

It was recognized long ago that agricultural research is logically a public function. This is because few individuals or even corporations have the scientific motive, the public spirit, the money or the economic incentive to do it thoroughly. As a private enterprise it generally does not pay, since the benefits can not be monopolized but must be shared with the community. Publicly conducted, however, it pays large returns. In fact, it is one of the greatest sources of private and national wealth.

Early in our history Congress stated the research principle which has ever



OLD ADMINISTRATION BUILDING OF THE U. S. DEPARTMENT OF AGRICULTURE,
BUILT IN 1868 AND TORN DOWN IN 1930.

since guided the department. In 1839 Congress appropriated \$1,000 "for collecting and distributing seeds, prosecuting agricultural investigations, and procuring agricultural statistics," and when the organic act creating the United States Department of Agriculture was passed in 1862, Congress directed the institution "to acquire and diffuse useful information on subjects connected with agriculture in the most general and comprehensive sense." With this principle the country has never quarreled.

Occasionally, however, it has questioned the manner in which the principle has been applied. It is raising some questions on this point now. There is a tendency to judge the worth of federal agricultural research by the prevailing condition of agriculture. Since farmers are not making money it is charged that research does not serve their interests directly. One might as well say that an army should drop its weapons whenever the battle goes against it.

Agricultural science is more valuable to farmers now than at any other time. It reduces their cost of production, strengthens their competitive position in the world's markets, and lays a foundation for aggressive action to regain prosperity. The unthinking say research should be dropped in times of depression, and technical progress with it, because science and technique cause overproduction. This is a very dangerous fallacy. It does not necessarily follow when science shows how to grow two blades of grass where one grew before that two blades should be grown. If the market is poor it is better to grow one blade at half the previous cost. Broadly considered, agricultural science facilitates control of the volume as well as of the cost of production.

Federal research in agricultural science has of course grown enormously since the country first recognized it as a proper governmental activity, and the

question whether the tree has been kept to the right size and shape and has branched in the right directions is entirely legitimate. I believe we may answer yes. The research system developed not from any preconceived plan, but gradually under the stimulus of keenly felt agricultural and national wants; hence it is not a mechanical creation but a living organism, evolving structurally and functionally in adaptation to its constantly changing environment. Thus in 1884 Congress appropriated money for the study and eradication of contagious pleuro-pneumonia, which had caused serious losses among live stock and prompted foreign countries to exclude animals from this country. The disease was investigated and stamped out and the export trade restored. This is a typical example of the way in which specific research projects in the department develop. Usually some situation demanding action gives the initial stimulus.

Concerning the test of results, I have no space to speak in detail. There is abundant evidence as to its substantial and many-sided character. Later articles in this series will furnish particulars. But I want to call attention to the fact that we can not measure the result in dollars and cents. It is too widely diffused and too complex for any such accounting. On each occasion when it has appeared in the United States the department has eradicated foot-and-mouth disease of cattle. What is the cash value of that achievement? We can merely guess how much damage the disease would have caused had it gained a foothold.

What is the value of hog-cholera control, of the increasing eradication of bovine tuberculosis, of the apparent extermination of the Mediterranean fruit-fly, of soil chemistry and soil surveys, of plant-disease prevention? It is literally incalculable, yet at the same time real and tangible.



ARLINGTON EXPERIMENT FARM.

The worth of federal research in agricultural science can not be measured in profits or even in exact degrees of agricultural advancement. Its benefits do not go exclusively to any group but become diffused throughout the community. Agricultural science developed in the department enters the general stream of science to stimulate and nourish the whole culture of mankind.

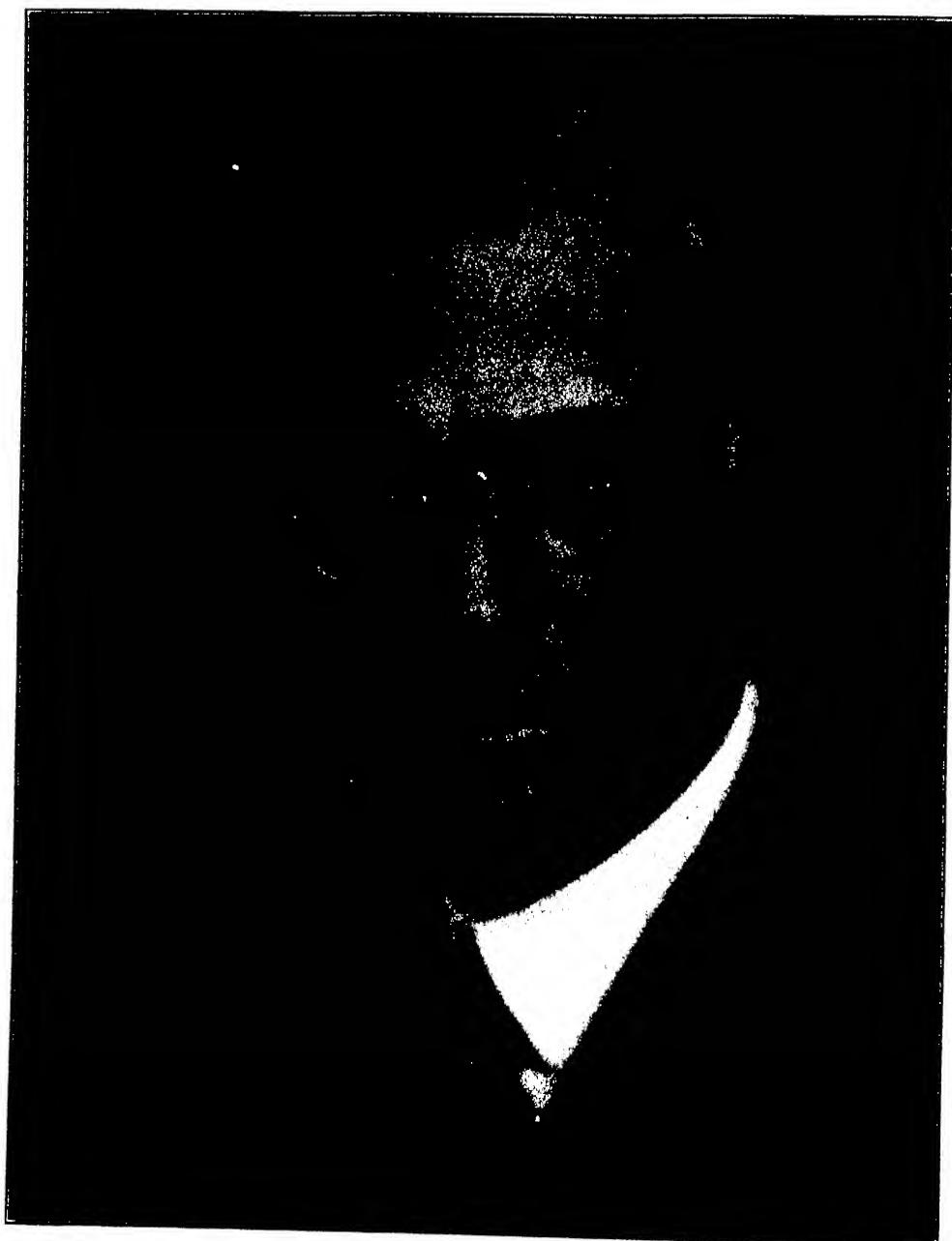
Let me give just two examples of fruitful research in the department:

Splenetic fever in cattle, formerly known as Texas fever, devastated the herds of Southern stockmen for decades. It gave foreign countries a reason for excluding American cattle and cattle products. It was the greatest obstacle to the Southern live-stock industry. Research in the Bureau of Animal Industry from 1888 to 1893 resulted in an epoch-making discovery. It demonstrated that a microorganism found in the blood of cattle affected with Texas fever was the actual cause of the disease and that the cattle tick is the means whereby the disease is transmitted. This was the first demonstration that a microbial disease can be transmitted exclusively through the agency of an intermediate host or carrier. Tick eradication work followed, with gradual suppression of the disease. But that result, though immensely important, was a mere detail compared with the vast significance of the discovery, which ranks among the great achievements of medical science. It led to the knowledge that such diseases as yellow fever, malaria, typhus fever, African sleeping sickness, Rocky Mountain fever and other maladies are carried through an intermediate host. It made possible the control of yellow fever in the Panama Canal Zone.

Sometimes research in the department anticipates the way to combat a plant disease. A brilliant modern example is the restoration of the sugar-cane industry in Louisiana, which not many years ago was threatened with extinction by

mosaic disease. It had been demonstrated many years previously that resistance to disease and also to climatic conditions is a genetic character that may be bred into or out of plants. Mosaic disease was discovered in 1919 in a small part of the sugar-cane area in eastern Louisiana. It spread rapidly through that state and into other sugar-cane growing states. Great areas of cane lands passed out of cultivation; sugar mills remained idle; and the sugar-cane industry faced collapse. Mosaic disease can not yet be cured because its nature is unknown. Accordingly the department undertook to develop resistant varieties. It imported strains known to be tolerant of the mosaic disease. These varieties, propagated from cuttings, were planted in 1928 on 135,000 acres in Louisiana. In 1929 the acreage planted to sugar-cane compared favorably with the acreage grown before the appearance of the mosaic disease.

Research in the department, though not carried on exclusively for the benefit of farmers, naturally interests farmers more than any other group. It discovers short cuts to the knowledge required in adapting agriculture to changing conditions. In a stable situation experience alone would eventually perfect an adequate technique. But no situation is stable. In a rapidly changing situation, like that with which farmers have now to deal, blind groping is too slow and costly a method of initiating necessary modifications in farm practices. Research, through observation and experiment under controlled conditions, establishes principles which lessen the risk of experimentation. Since experimentation is obligatory, whatever helps to give it purpose and direction reduces farm expenses as definitely and tangibly as a new machine or a higher yielding crop. In other words, research is the farmer's best guide to the avoidance of useless struggles.



ARTHUR M. HYDE
SECRETARY OF AGRICULTURE.

THE DEVELOPMENT OF AGRICULTURAL RESEARCH AND EDUCATION UNDER THE FEDERAL GOVERNMENT

By Dr. A. F. WOODS

DIRECTOR OF SCIENTIFIC WORK, UNITED STATES DEPARTMENT OF AGRICULTURE

ONE of the most valuable fruits of the Renaissance was a realization that education must deal more with reality and the application of knowledge to the problems of every-day life. Many schools were established with this in view. Modern science had its birth in this idea of studying nature by observation and experiment. From such studies gradually grew the sciences of physics, chemistry, biology and geology, and their applications to every-day life. It soon became apparent to all that *real knowledge* was useful.

As accurate knowledge increased and we developed increasing control of natural forces and things, there was an increasing desire on the part of people generally for the benefits that might flow from such knowledge. To trace the history of this great development would be impossible in this paper, but we should recognize that out of these beginnings in the sixteenth and seventeenth centuries grew the science of to-day and our own appreciation of the economic and social value of science and research. Its importance was realized by many of the leading spirits in our own early history, especially by Franklin, Jefferson and Washington.

In his first message to Congress in 1790 Washington suggested that science and literature might be promoted by the institution of a national university, and in 1796 he definitely recommended the establishment of such an institution.

In his last message to Congress, on December 7, 1796, Washington said: "In proportion as nations advance in popu-

lation the cultivation of the soil becomes more and more an object of public patronage." Washington recommended that appropriate steps be taken by Congress to promote agriculture in the United States. Congress gave much consideration to ways in which this might be done. Agricultural societies were organized and devoted much thought to the subject. A full realization of Washington's idea was not consummated until long after his death. The great agricultural and industrial expansion growing out of the settlement of the West, the decline of agriculture in the older settled portions of the East, the need for better crop plants and domestic animals, the need for new crops better adapted to the changing requirements, led the United States Agricultural Society, which was established to carry out Washington's idea, to adopt a resolution at its meeting on February 2, 1853, favoring a department of agriculture, with a cabinet officer at its head. The society was very active in presenting this idea to Congress and to the public.

Such plans received strong support from leaders of thought, educators, state legislatures and members of Congress. They finally crystallized into the act establishing the United States Department of Agriculture, passed by Congress in 1862 and signed by President Lincoln on May 15 of that year, and the Morrill Act, signed by Lincoln on July 2 following, establishing the land-grant colleges.

The organic act establishing the Department of Agriculture is very broad:



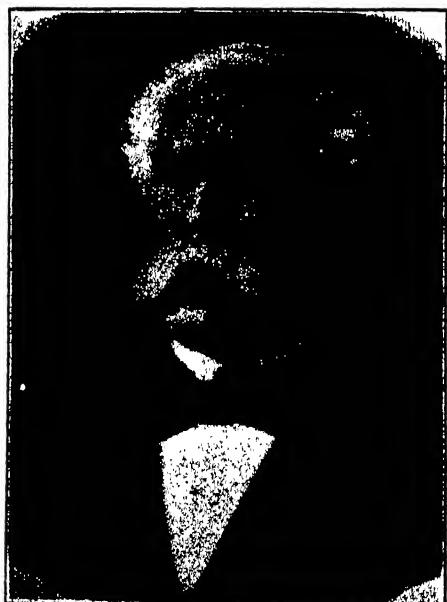
ISAAC NEWTON
COMMISSIONER OF AGRICULTURE, 1862-1867.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That there is hereby established at the seat of Government of the United States a Department of Agriculture, the general designs and duties of which shall be to acquire and diffuse among the people of the United States useful information on subjects connected with agriculture in the most general and comprehensive sense of that word, and to procure, propagate, and distribute among the people new and valuable seeds and plants.

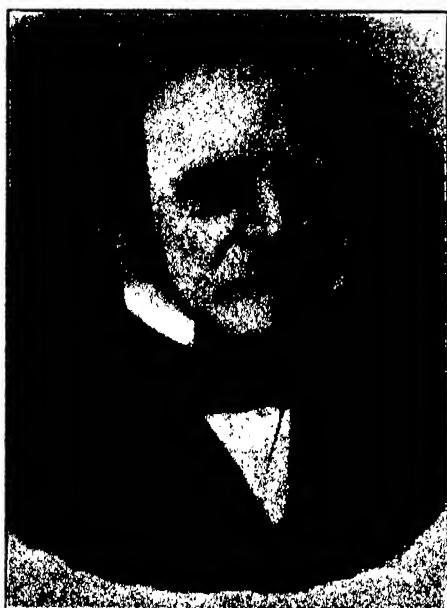
Agricultural work previously done through the Patent Office was transferred to the new department, and the portion of the mall now occupied by the department was transferred to it. Isaac Newton, the first agricultural commissioner, personally supervised the laying out of the tract, as an experimental farm. Commissioner Newton suffered a sun-stroke while supervising some work on this farm in July, 1866, and died from the effects about a year later. He appointed William Saunders, who later be-

came famous as the landscape designer of Gettysburg Cemetery, as superintendent of the propagating garden. This was the first step in what is now the department's Bureau of Plant Industry. He also appointed C. M. Wetherill department chemist. This appointment led in time to the Bureau of Chemistry. In 1863 Lewis Bollman was made statistician. His work grew into the statistical service, now a part of the Bureau of Agricultural Economics. Townsend Glover was appointed entomologist and was thus the father of the Bureau of Entomology. Newton took over the publication of meteorological data gathered by the Smithsonian Institution. This was transferred to the Signal Service of the Army by Congressional act in 1872, and transferred again to the Department of Agriculture by Congress on October 1, 1890.

The first building for the department was erected during the administration of Commissioner Capron, 1867-71. He was especially commended for keeping the



HORACE CAPRON
COMMISSIONER OF AGRICULTURE, 1867-1871.



FREDERICK WATTS
COMMISSIONER OF AGRICULTURE, 1871-1877.

cost within the amount appropriated. About this time Texas fever of cattle became a serious menace, and the Division of Veterinary Surgery was established to study this and other diseases of live stock.

During this period also, at the suggestion of Professor Joseph Henry, of the Smithsonian Institution, a Division of Botany was organized for the special purpose of making a scientific study of economic plants. Commissioner Capron resigned in 1871 to become agricultural adviser for the Government of Japan.

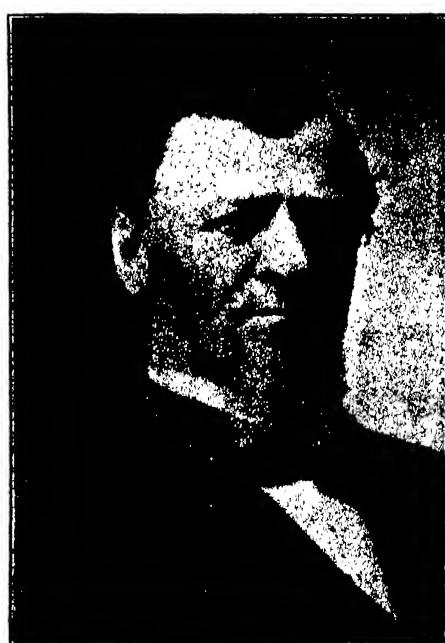
The next commissioner, Frederic Watts, found in successful operation the Division of Chemistry, Gardens and Grounds, Entomology, Statistics and Botany. He organized a Division of Microscopy, which gave special attention to mushroom cultivation, cranberry rot, mildew of grapes, peach yellows and black knot of plums.

Succeeding commissioners, Le Due, Loring and Colman, perfected the work

already established. The Division of Forestry was organized during this period, thus laying the groundwork for what is now the Forest Service.

The outstanding accomplishment during the administration of Commissioner Loring was the introduction and distribution of the Bahia seedless orange, now known as the Washington Navel, yielding about 35 million dollars a year to California. He reorganized and enlarged the Division of Statistics into an official crop-reporting agency, and placed an agent with the Consul General in London for collection of information on the foreign demand for agricultural products.

During the latter part of Commissioner Loring's administration the law creating the Bureau of Animal Industry was passed by Congress and approved on May 29, 1884. This was in response to a growing realization of the losses caused by animal diseases, such as pleuro-pneumonia, and the dangers of



WILLIAM G. LE DUC
COMMISSIONER OF AGRICULTURE, 1877-1881.



GEORGE B. LORING
COMMISSIONER OF AGRICULTURE, 1881-1885.



NORMAN J. COLMAN
COMMISSIONER AND SECRETARY OF AGRICULTURE, 1885-1889.



JEREMIAH M. RUSK
SECRETARY OF AGRICULTURE, 1889-1893.



J. STERLING MORTON
SECRETARY OF AGRICULTURE, 1893-1897.

spread of this and other infectious and communicable diseases of live stock. Broad powers of study and control were given, including quarantine and eradication. Almost every phase of animal industry as now organized was foreshadowed in this bill.

During Commissioner Colman's administration, 1885-89, the Hatch Act, establishing the agricultural experiment stations, was passed by Congress (1887). These stations were to be supervised in a general way by the federal Department of Agriculture. The Office of Experiment Stations was organized for that purpose.

During this period the rapidly expanding horticultural interests of the country, with increasing losses from causes which were obscure, led to greater emphasis on these problems. A Division of Pomology was organized to bring together scattered information on fruits. A Section of Mycology was organized in the Division of Botany to give special attention to fruit diseases, particularly those of the grape and peach. A Division of Ornithology and Mammalogy was established, especially to study the damage done to crops and fruits by birds. This latter grew into a more extended study of the beneficial and harmful species of wild life in general and developed into the Bureau of Biological Survey.

By act of Congress approved by President Cleveland on February 9, 1889, the Department of Agriculture became an executive department under the control of a secretary, appointed by the President, with the advice and consent of the Senate. The secretary therefore became a member of the President's cabinet. Commissioner Colman was appointed secretary, retaining the position to the end of the administration, a little less than a month.

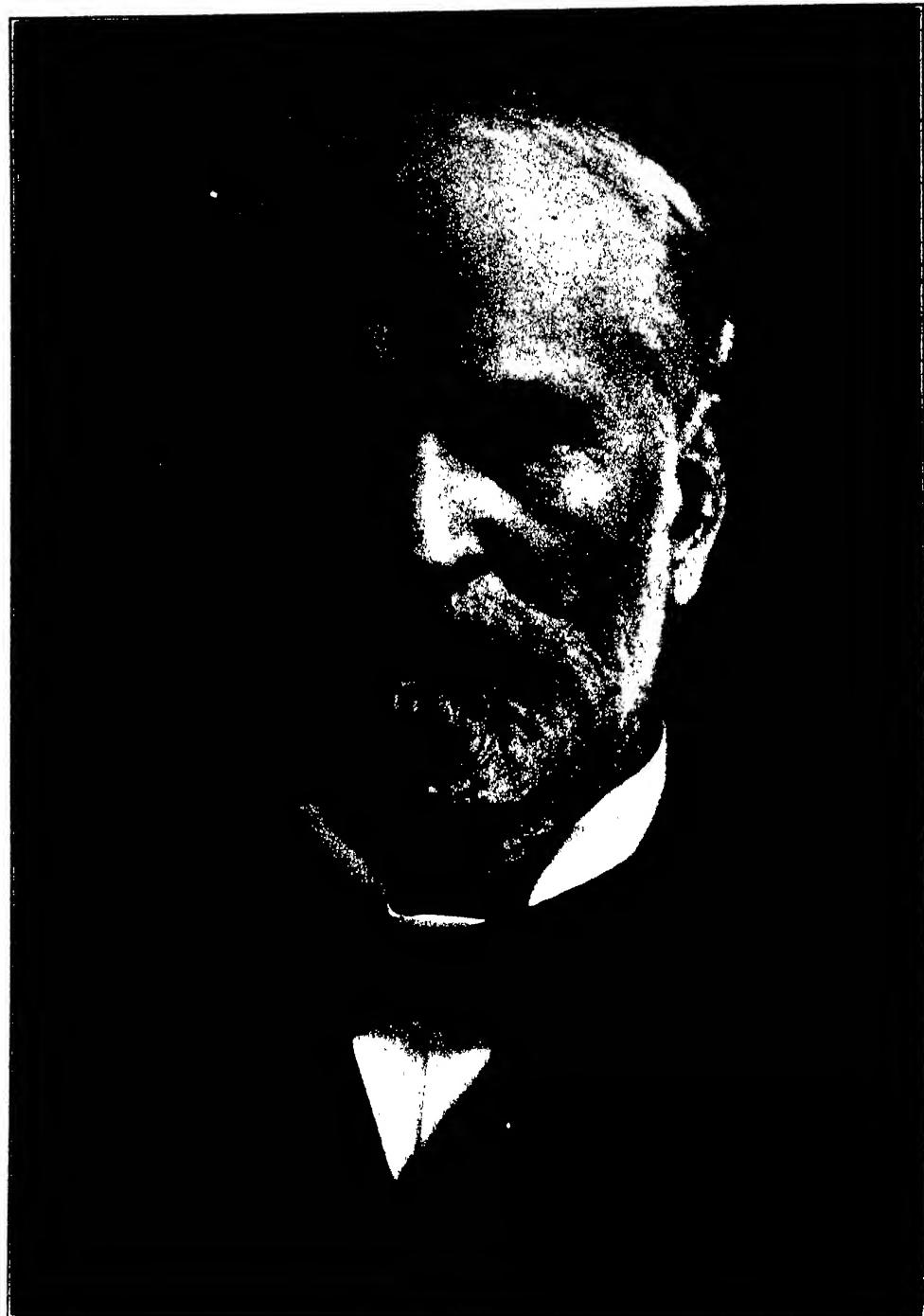
Jeremiah Rusk was appointed secretary during the administration of Presi-

dent Harrison. He inaugurated the *Farmers' Bulletin* series and organized the editorial and publishing work of the department into a Division of Records and Editing, which has passed through several transformations and is now the Office of Information, handling all publications and information activities for the department as a whole.

During this period meat inspection for export and interstate commerce was inaugurated as a result of growing complaints against exportation of diseased meat. Progress was made in the study and control of Texas fever. The discovery was made that the parasite causing the fever was carried and conveyed by the bite of an infected tick, thus opening up an entirely new field of disease transmission.

The Weather Bureau was transferred from the Signal Service to the Department of Agriculture under the Cleveland administration. Hon. J. Sterling Morton, of Arbor-day fame, became secretary. He reorganized and enlarged the forestry work, organized the Division of Agrostology for the study of forage plants; established the Division of Soils and Soil Survey; established the Office of Road Inquiry, now the Bureau of Public Roads; organized a Dairy Division in the Bureau of Animal Industry; consolidated the Division of Microscopy with the Division of Mycology and Plant Pathology and encouraged the extension of Civil Service regulations through the department. He attempted to abolish Congressional free-seed distribution, discontinued the Annual Reports, and established the Yearbook series.

James Wilson, of Iowa, became secretary in 1897. His administration (1897-1913) was notable for reorganization and consolidation of related fields of work. The divisions dealing with plants were combined into a Bureau of Plant Industry. Farm-management work was



JAMES WILSON
SECRETARY OF AGRICULTURE, 1897-1913.

organized in the bureau, and special studies of marketing problems inaugurated. Regional studies of key-crop industries were begun to find what was most needed to improve the agricultural industries and to put them on a more permanent basis. Agricultural explorations were undertaken to find improved varieties of crop plants for direct use and for crop-breeding purposes. Many valuable introductions were made, among these the durum wheats, now the basis of the American macaroni industry; the hardy Turkey wheats from Russia, which have revolutionized wheat-growing in the Great Plains; hardy alfalfa and a host of other legumes and forage plants; many new varieties of soy-beans; the date palm and the Chinese date or jujube; Smyrna figs; Oriental persimmon. Much attention was given to plant breeding, especially to the production of disease-resistant varieties.

The work of the Division of Soils was expanded into a bureau, with special reference to the factors determining fertility. Soil surveys were speeded up, and special attention was given to the adaptation of the soil types to special crops. The work of the Division of Forestry was enlarged, especially by transfer of the forest reserves to the department. Congress also authorized the President to set apart additional reserves. A comprehensive plan of forest conservation was developed. The division became the Bureau of Forestry, or the Forest Service, as it is now known. The Division of Chemistry gave special attention to problems of food control and laid the groundwork of the Pure Food Law, which for many years was administered by this division, which became the Bureau of Chemistry.

The Division of Ornithology and Mammalogy had developed much valuable information regarding useful and harmful birds and mammals. Several acts of Congress had placed on the de-

partment the responsibility of regulating the importation and killing of certain species. Bird refuges and game preserves were established. The work was reorganized as the Bureau of Biological Survey.

The work of the Division of Entomology had developed, especially on the control of cotton boll weevil, pink boll worm and similar pests. The division was reorganized as a bureau. In 1903 the building of the east and west wings of the new building for the department were authorized, leaving a central unit to be provided. This latter has recently been completed and occupied.

The outstanding feature of the administration of Secretary Houston (1913-1919) was the consolidation of the economic, statistical and marketing work into a Bureau of Markets, now the Bureau of Agricultural Economics, which took out of the other bureaus this type of work and unified it.

Secretary Wallace's administration (1921-24) was characterized by a special examination of the status and needs of the various branches of agricultural industry, especially from the economic aspects. He further grouped the main functions of the department for general administration purposes into scientific work, regulatory work, extension, information and business administration, with a director, ranking as an assistant secretary, in charge of each. The purpose of this was to bring about better cooperation and correlation and more uniform policies.

The next important reorganization step was the separation of regulatory work from research, taken during Secretary Jardine's administration (1925-29). The food, drug and insecticide control was taken out of the Bureau of Chemistry and set up as a special service dealing only with the regulatory features of the work, the research remaining in the research bureaus. Plant



DAVID F. HOUSTON
SECRETARY OF AGRICULTURE, 1913-1919.

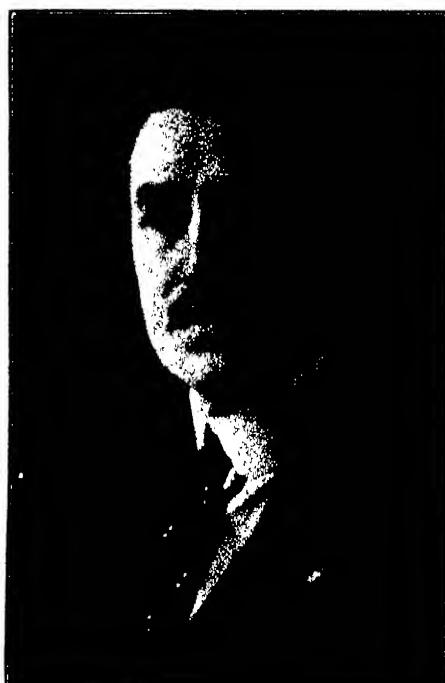
quarantine and control functions were removed from the Bureau of Plant Industry and the Bureau of Entomology and organized as a service unit. The regulatory and research work have been much more effective since this separation. Close cooperation is maintained so that any research needed by the regulatory units can be promptly taken care of.

The Bureau of Chemistry, Bureau of Soils and the Fixed Nitrogen Laboratory, having much in common, were consolidated into a single Bureau of Chemistry and Soils, and the soil fertility work of the Bureau of Plant Industry transferred to the new bureau.

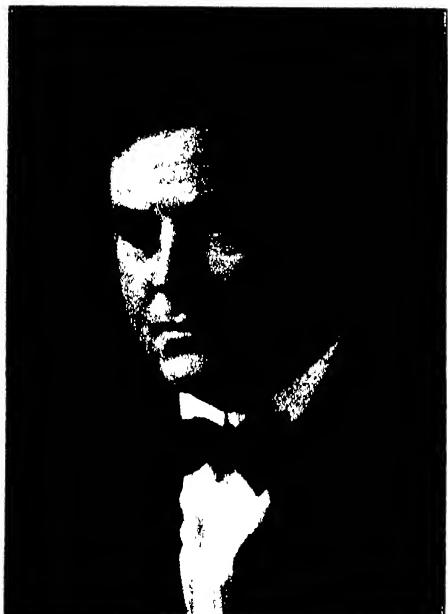
The present administration under Secretary Hyde is emphasizing a clearer distinction between Federal and State responsibility, elimination of duplication within and outside the department, better correlation of state and federal

work. All work is rapidly being reduced to a definite project basis and the work of the department restricted to the larger regional problems and those requiring the cooperation of the states and federal government. Local matters are being turned back to the states.

In 1887 the Hatch Act was passed, establishing the experiment stations in connection with the land-grant colleges and providing for close relations with the federal Department of Agriculture. This was later supplemented by the Adams and Purnell acts. All these acts have been supplemented from time to time with legislation enlarging the scope, increasing the funds and providing for closer correlation of work. Under the stimulus of these acts there has been built up a group of closely affiliated educational and research agencies, federal and state, that are devoting their energies to improving agriculture and



EDWIN T. MEREDITH
SECRETARY OF AGRICULTURE, 1919-1921.



HENRY C. WALLACE
SECRETARY OF AGRICULTURE, 1921-1924.



HOWARD M. GORE
SECRETARY OF AGRICULTURE, 1924-1925.

country life and related industries, and rendering service in many ways to the nation as a whole.

It was Bacon who coined the phrase "Knowledge is power." Scientific research supplies the facts that are the basis of knowledge. It is *industry* that has brought knowledge into the everyday realization of humanity by making



WILLIAM M. JARDINE
SECRETARY OF AGRICULTURE, 1925-1929.

life easier, safer, happier and more satisfying through the development of mechanisms that apply human intelligence automatically to a very large degree and utilize the unseen energies of the universe for the good of man.

In this group I also include that great group of industries known under the general designation of agriculture. Agriculture and the mechanic arts develop hand in hand. Food and raw materials grown on our cultivated lands and in our forests and transformed by animals and by manufacture in a thou-



A MISSOURI FARM HOME, HARRISONVILLE, MISSOURI.

sand ways are fundamental to all the rest. It was and is therefore the concern of all our people that this reservoir of power shall not be depleted but remain for all time as the source from which life-sustaining power may be always available.

Man power, food and raiment, materials for home and for industry are the elementary products. Every civilization that has neglected this source of renewing its energy has decayed. The founders of this republic determined from the beginning that it should not suffer the fate of other civilizations that forgot agriculture and perished.

The Department of Agriculture and the land-grant colleges, the experiment stations and the extension service are agencies that find the facts in respect to climates, soils, crops, animals, foods and products of farm and forest, and see that these facts are made available to the people. The work includes production,

conservation and distribution and use for the welfare of all concerned.

On this foundation commerce and industry rest as on a rock. If the foundation is secure all is well, but if it is insecure the superstructure falls. No thinking person to-day disputes the wisdom of that policy established by our fathers of doing everything possible to insure the security and permanency of agriculture as the foundation of national security.

Perhaps nowhere in our lives is the educative value of responsibility and independent effort more evident than on the farm. The farm boy and girl are intelligent and alert about many things not found in text-books. They meet and control many difficult situations—problems of weather, soils, pests, competition, isolation. The farmer has thus come to depend largely upon his own efforts and judgment. This has bred up a race of

men and women noted for their independence.

It is the farm-trained boys and girls that have developed into the great leaders in industry, commerce, education, the ministry and other professions. This contribution of real men and women to the life of the nation is one of our greatest assets. Dr. Liberty Hyde Bailey has forcefully expressed this in the "Farmer's Challenge" in his book of poems entitled "Wind and Weather," published by the Macmillan Company:

Blow ye winds and lay on ye storms
And come ye pests in rabble swarms
And fall ye blights in legion forms--
I am here; I surrender not
Nor yield my place one piece or jot--
For these are my lands
And these are my hands
And I am bone of the folk that relentlessly
stands.

The blood of old plowmen runs hard in my arm
Of axemen and yeomen and battlemen all
Who fought and who flinched not by marsh or
wall
Who met the bold day and chased ev'ry alarm;
My fatherkind sleep, but I hear the old call
And fight the hot battle by forge and by
farm--

For these are my lands
And these are my hands
And I am bone of the folk that relentlessly
stands.

Farming is a life as well as a business and we must not lose its values by too great isolation and lack of organization on the one hand or too great industrialization on the other. Either extreme would be bad for the farmers as well as for the nation.

The rural economic and social unit is the farm family. There are about six million farm families, constituting about one fourth of our population. The problem before us is how we can help the rural population to help themselves; to have comfortable homes, paying farms, good roads, schools and churches; to maintain their individual independence and yet act together for their common welfare.

Here arise new difficulties that are partly local and partly state and national in their aspects.

We desire to solve the problem without too greatly reducing our rural population in relation to urban. We desire



A MODERN FARMSTEAD IN PENNSYLVANIA.



A TYPICAL FARMSTEAD OF AVERAGE SIZE.

to maintain on the land our most virile people—at least there should be no reduction in quality. To accomplish this there must be as good opportunity for the country boy and girl to get the worth-while things in life as there is for the city boy and girl. This means good homes, good farms, good schools and co-operation.

The starting point in agriculture is soil. If the soil is good and adapted to the crops grown we have the foundation of good agriculture. If the soil is not good or not adapted to crops grown we have the beginning of the failure.

We have no scientific land policy in America. We have cut down the forest and plowed up the prairie and put the land into corn, wheat and cotton, cattle, pigs and poultry, with no regard to soil or market requirements or competing areas. We have built up one community only to have it pushed to the verge of bankruptcy by developing new areas. Millions of acres of land adapted only for forests or range have been sold for general farming purposes. There is no present need for these lands in general crop production, but there is a real need

for them in forest or pasture, in which they will give good economic return in the production of wood and other needed forest products or in the production of grass.

We are using our timber resources four times as fast as they are being reproduced. Unwise removal of forest and grass cover is causing rapid run-off of rainfall, causing erosion and land destruction, the filling of stream beds, with resulting floods, etc. By so doing we are opening Pandora's Box for our children, if not for ourselves, and wasting billions of dollars of wealth each year.

The need for a sound, wise government policy, backed by public opinion, is essential to our present and future welfare.

The federal Department of Agriculture and the land-grant colleges have long stood for such a policy and are doing everything in their power to bring it about. They have been making soil surveys and soil studies for many years. They have done much towards pointing out areas and soil types that should be devoted to state and national forests and

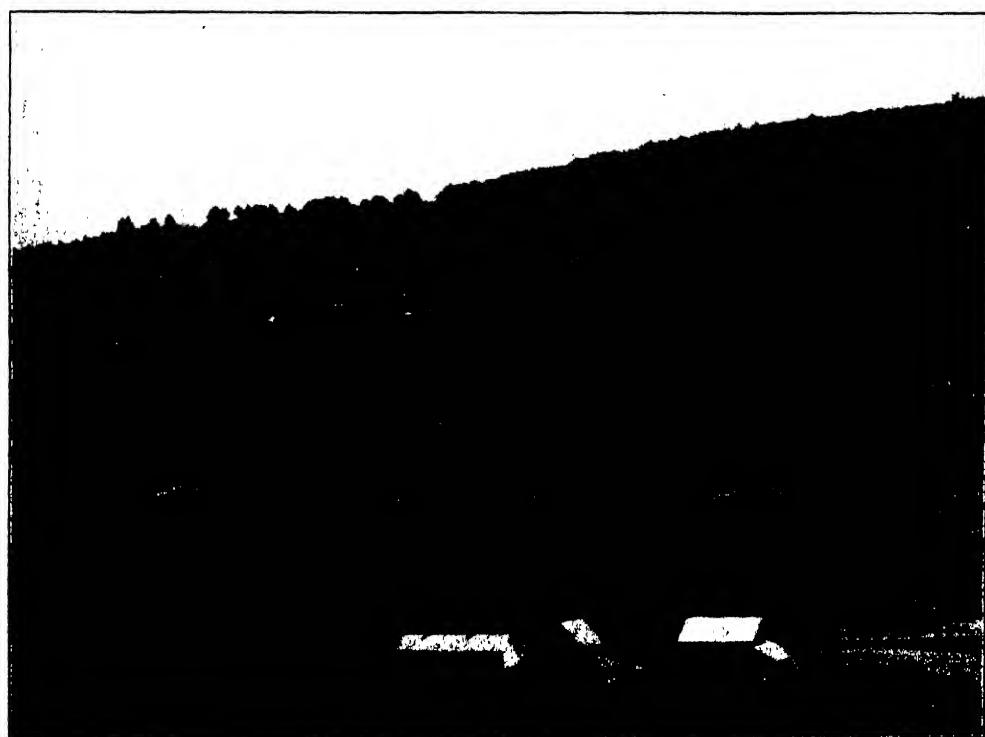
those adapted to staple crops. They have aided in formulating legislation to protect and promote the policy, but progress is very slow, due to lack of public understanding of the problems involved.

A sound land-utilization policy is the first step in the solution of our so-called agricultural problem. It would bring no more non-agricultural land into crop production. It would gradually bring back into forest or pasture land that is already unprofitably farmed and thus put it on a paying basis. This would tend to stabilize crop production and reduce surpluses. It would tend to stabilize the business of wood production and business based on forest products generally. It would help to prevent erosion, regulate stream flow, conserve water resources, including fish and game,

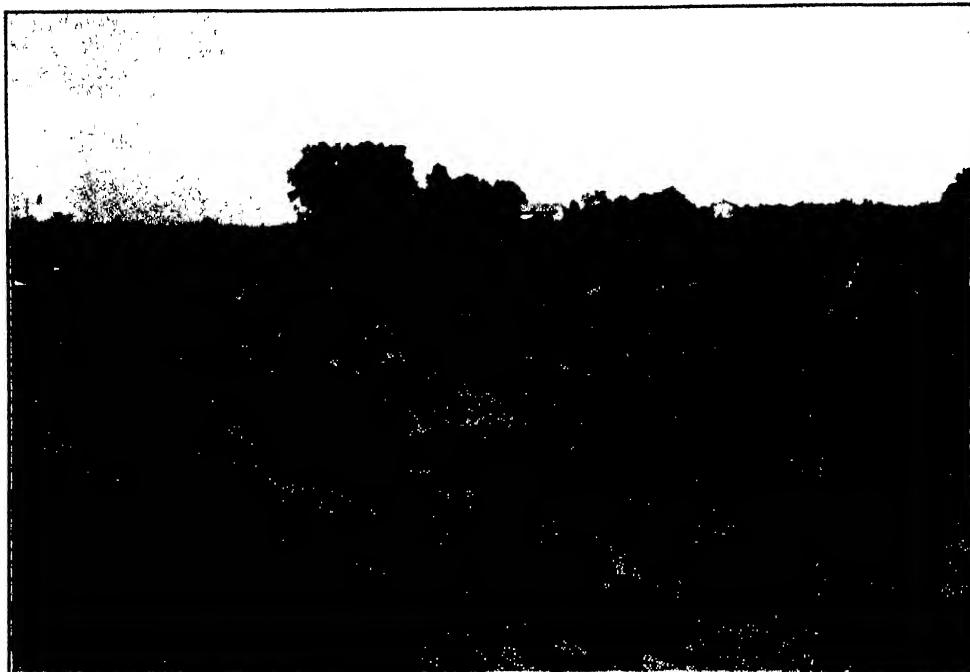
and, last but not least, *water power*. The direct and indirect benefits of such a policy will be apparent to any one who gives the matter careful thought.

Coming back to our good agricultural land, we find that, too, must be protected on steeper slopes, at least from erosion, by proper terracing and planting. We lose by erosion 20 times as much fertility in large areas of fertile soil as is taken out by crops, and worst of all we gradually lose the soil itself. This can usually be prevented by proper cultural practice.

We know, too, that fertility is itself a complex matter, involving microorganisms, bacteria, protozoa, worms, algae, fungi, and numerous other kinds of living organisms, some harmful, some helpful. These have their effects on the



FARMING ON SUCH A STEEP ROCKY SLOPE,
WHICH IS UNTILLABLE AND NOT PASTURABLE FROM THE STANDPOINT OF ECONOMY, SHOULD NOT BE
UNDERTAKEN.



TERRACES TEN YEARS OLD IN ARKANSAS HAVE CONSERVED SOIL.

inorganic materials forming the body of the soil, and the nature of those inorganic materials and their solutions and content of air and water all are involved. If conditions are right fertility may be maintained and improved. If they are wrong fertility may be lost.

Crops constantly take out of the soil materials that must be replaced. Here comes in the problem of fertilizers and their use.

These problems are too complex for the farmer to work out for himself, so there has been a wise provision by the Federal Government and the states to provide for such study through the experiment stations, the land-grant colleges and the research bureaus of the U. S. Department of Agriculture. It would be impossible for individual farmers or groups of farmers to undertake such work except in highly specialized industries.

Next to the soil the most important

factor in successful agriculture is the plant, the great converter or transformer of sunlight and soil into forms available as food for animals. If green plants should perish from the earth all animal life would soon die. If the farmers should cease their labors for a few months civilization would quickly decay, cities would disappear and men would become beasts of the forest. So agricultural plants and the men who grow them are important factors, worthy of the most careful thought of all people.

One plant differs from another plant in its ability to live and work under given conditions, adaptation to soils, to climates, resistance to diseases and insects, ability to produce the products desired, etc. Plants that are not adapted are inefficient and result in failure or loss to those growing them.

Here again the great research agencies of the Department of Agriculture and the state experiment stations are doing

much to help the farmer get crop plants that are best adapted and most efficient for the conditions he has to meet. Agricultural explorers search the world for needed material for direct use or for breeding purposes. Improved varieties of cotton and corn, grasses and clovers, wheat and other small grains, have more than doubled the average yield since this work began. *Quality* has been greatly increased. Adjustments to climate, soil and market needs have been and are being made. Resistance to disease and insect pests have been worked out, and much work is in progress. In this field of disease and pest control great advances are possible, as losses that might be prevented are still enormous, aggregating several billion dollars a year. Manifestly here again the individual must be aided by the government and the state in the interest of public welfare.

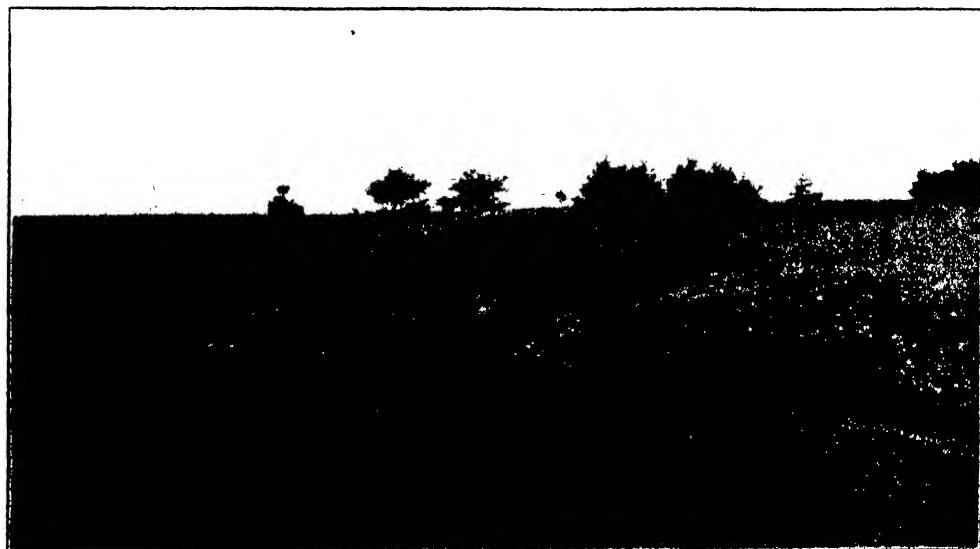
What has been said about plants is true also of farm animals. One cow differs from another cow in meat and milk and butter-fat producing power. Some cows do not pay their board bill; others

on the same feed yield a good profit. The same is true of poultry and hogs.

Then there is a host of insect pests and diseases to combat. All these require careful study in order to control them. Here again the federal department and the state experiment stations help the farmer in the interest of public welfare.

Soils and crops and animals are not all. There is the question of economics of production; the combinations of crops and animals; the most economic use of machinery, labor and capital; the problem of markets; home and foreign marketing methods; cooperation; market information; standardization; grades; finance; transportation; etc., etc. This involves world study and statistics on a large scale. It is, for agriculture at least, manifestly a federal and state function.

The Bureau of Agricultural Economics of the federal Department of Agriculture makes these studies for agriculture, cooperating in many phases of the work with the Department of Commerce, which makes similar studies for commerce and industry. Sound business



PINE TREES CHECKED EROSION IN THIS GEORGIA PASTURE.



SOUTHERN COUNTY AGENT HOLDS A TERRACING DEMONSTRATION TO SHOW HOW TO PREVENT SOIL EROSION.

methods applied to agriculture with effective organization and cooperation will add greatly to its stability and attractiveness as well as efficiency.

One of the most potent forces influencing production is weather. Favorable or unfavorable weather has more to do with volume and quality of production than any other group of factors. Except in very intensive agriculture under glass, weather can not be controlled except within narrow limits. On a limited scale fruit can be protected from frost by smudging. Electric light can in a small measure intensify light when needed. Drainage can overcome the effects of too great rainfall and irrigation provide for a lack of it. But all these methods are applicable only on a small scale in intensive industries.

Usually and generally the farmer must have crops adapted to the range of temperature and moisture conditions. To

do this intelligently and safely he must have accurate data as to early and late frost, maximum and minimum temperatures, rainfall, wind velocity and sunshine and cloudy weather or light intensity.

Thus the Weather Bureau of the United States Department of Agriculture provides not only for the farmer but for commerce and industry, shipping, air service, army and navy, and the people generally. It has come to be so much a part of our life that we hardly realize that it takes a great mechanism operating night and day every day in the year over a large part of the world to do the job.

There is the engineering side of agriculture—farm machinery, construction of buildings, the use of power, terracing, drainage, irrigation, road construction, etc. To furnish information in these fields we have the Bureau of Agricul-

tural Engineering of the Department of Agriculture. Much help is also available through the engineering departments of the land-grant colleges. The advance in machinery has greatly reduced labor costs and increased output per worker on the farms as well as in industry. It has done away with drudgery on the farm and in the farm home to a considerable extent.

The great national cooperation in road construction is carried on under the Bureau of Public Roads.

So much for the business side of agriculture. Let us look for a moment on the social side centered in the home. Here great changes are rapidly coming about as a result of the new developments in home economics in the colleges and the Bureau of Home Economics of the Department of Agriculture. Home planning to reduce labor, improve sanitation and comfort and preserve beauty are now subjects of interest to farm women. The same is true relative to clothing.

Food values have taken on a new interest since the discovery of vitamins and their importance to health, in which the experiment stations and the department have taken a very large part. New and improved methods of cooking and preserving and serving foods of various kinds are being worked out. Extensive studies are being made of the social factors in rural life and methods of improving them. This applies especially to the school and church.

Much attention is being given also to recreation and public entertainment and all the other factors that create interest and satisfaction in life.

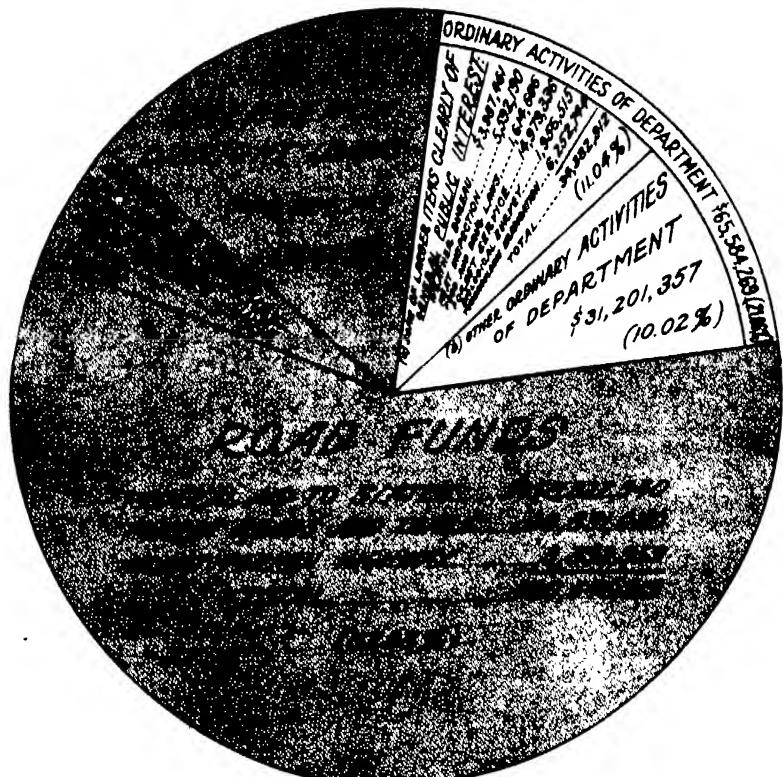
The Purnell Act, recently passed by Congress, provides for extending the research functions of the agricultural experiment stations of the land-grant colleges to include home economics and rural sociology. Much valuable work has been started in this field, much of it in cooperation with the Federal Department of Agriculture.

Rural free delivery, the telephone and



A MECHANIZED FARM

THIRTEEN COMBINES HARVESTING ON A 6,500 ACRE WHEAT RANCH IN ADRIAN, TEXAS.



A CLASSIFICATION OF THE TOTAL EXPENDITURES CHARGED TO THE DEPARTMENT OF AGRICULTURE FOR THE FISCAL YEAR 1931.

the radio, improved roads and the automobile have so reduced distance and time that rural isolation is largely a thing of the past. It is not at all uncommon for a whole family to drive a hundred miles to a conference.

Yet the large number of units to deal with and the complexity of the problems involved and the regional and local adjustments constantly required makes it necessary to have a special form of educational work known as Agricultural and Home Economic Extension. This was provided for under the Federal Smith-Lever Act, which became a law in 1914. The land-grant college in each state, cooperating with the federal Department of Agriculture, provides farm and home demonstration agents in most of the agricultural counties of the United

States. The agents live and work in each community and keep the farmer in touch with specialists in the various fields in which he is interested. This is proving to be one of the most effective extensions of the land-grant college plan that has ever been undertaken. Through its development we may hope to maintain that is necessary for the most efficient basis and still secure that cooperation that is necessary for the most efficient business operation and satisfactory living.

The social values of rural life at its best may thus be conserved along with improved economic conditions. This is more in accord with our American democratic ideals than the more complete industrialization on the one hand or peasantry on the other.

To review briefly, therefore, the federal Department of Agriculture is an arm of the government established especially to promote agriculture by research, education, extension, and special types of service. It cooperates in this work especially with the land-grant colleges of the states, including the experiment stations and extension services. These agencies, working in harmony, are developing an agricultural policy for the United States in cooperation with the rural people.

One other phase of the work of the federal Department of Agriculture should be mentioned: *viz.*, the regulatory. Enforcement of the Pure Food and Drugs Act has very close relations to producers, manufacturers, dispensers and users of food products and drugs passing in interstate commerce. Purity and honest labeling are the main purposes of the act. It has had much to do in bringing about these desired objectives.

The meat inspection law, in force as to all meat passing in interstate commerce, with federal inspectors in all markets doing an interstate business, protects the meat users of the nation and the world so far as they use meats produced in the United States.

The department enforces the Migratory-bird Treaty Act, the Grain Stand-

ards Act, Federal Horticultural Inspection and Quarantine, Warehouse Act and various other acts involving agricultural products or protection of agriculture or the consumers of agricultural products.

Eradication and control work involves such projects as tick eradication, tuberculosis eradication, eradication of foot and mouth disease, hog cholera control and control of other epidemic diseases of animals, blister-rust control of white pine, barberry eradication for the control of wheat rust, eradication of citrus canker, etc. In the insect field we have the control of the corn borer and other moths, Japanese beetle, Mexican fruit-fly, eradication of pink boll worm of cotton, control of the cotton boll weevil, etc.

The service work includes such activities as the administration and protection of the national forests, the weather service, crop and live-stock estimating, market news service, shipping point and terminal market inspection on perishable farm products, and other work of like character for the benefit of the public.

The accompanying statement and chart, prepared by Mr. Jump, the budget officer of the Department of Agriculture, gives the clearest possible picture of how money appropriated to the Department of Agriculture is used:

Expenditures of the Department of Agriculture for the fiscal year 1931, on basis of budget statement No. 8, pages 482-447 of Federal Budget for 1933

	Per cent.
1. Roads	
Federal aid to States	\$158,322,940
Forest roads and trails	18,831,020
Mt. Vernon Highway	3,392,959
Total for above roads	<u>\$180,546,919</u> 57.98
2. Emergency drought loans	48,824,743 15.68
3. Payments to States:	
State experiment stations	4,840,000
Extension work	8,650,229
Forest fire prevention, etc.	3,434,038
Total payments to States, as above	<u>16,424,262</u> 5.28

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4. Ordinary activities of Department, including (a) Some of the larger items of public interest, as follows:		Per cent.
Weather Bureau (general)	2,745,834	
Weather Bureau (for aviation)	1,241,627	
Meat inspection	5,592,190	
Food and drug laws	1,614,666	
Forest Service	14,979,336	
Biological Survey	1,956,515	
Tuberculosis eradication	6,252,744	
 Total above items (11.04 per cent.)	 34,382,912	
(b) Remainder (10.02)	31,201,357	
 Total for ordinary activities of departments	 65,584,296	21.06
5. Total, Dept. of Agr., all purposes	311,380,193	100
Less checks issued but unpaid June 30, 1931	14,514,248	
 6. Net cash withdrawal from Treasury	 296,865,945	
Total expenditures of Federal Government withdrawals from Treasury, net cash, including payments from postal revenues	4,877,315,309	
 Relation of Department of Agriculture expenditures of Government:		
All purposes, on basis of net cash withdrawals (\$296,865,945)	6.09	
Deduct roads and drought loans, leaving	82,008,531	1.68
Deduct roads, drought loans, and payments to States, leaving	65,584,269	1.34
Deduct roads, drought loans, payments to States, and certain of the larger items of general public interest, as listed above, leaving remainder of 31,201,357	0.64	

THE OBLIGATION OF UNIVERSITIES TO THE SOCIAL ORDER¹

THE UNIVERSITY AND GOVERNMENTAL CHANGES

By Dr. HAROLD GLENN MOULTON
PRESIDENT OF THE BROOKINGS INSTITUTION

THERE is expressed in the very wording of the subject before us, "The University and Governmental Changes"—a wording for which I am in no degree responsible—a social philosophy which may well serve as an introduction to our entire discussion. In this pragmatic conception, governmental structures, even principles of government, are evidently viewed as subject to a continuous process of adaptation to the needs of an evolving economic and social organism. Before beginning this evening's discussions of the relations of the university to the changing problems of government, it may perhaps be useful for us to recall that there are two fundamentally different conceptions of the province of government. If we adhere to one of these theories, the part that the university might play is negligible; but if we accept the other, the opportunity of the university—and indeed its responsibility—is most important.

The first of these conceptions is that the government should play a passive rôle in human affairs. The origin of this philosophy of government may be explained as follows: The gradual emergence of the scientific spirit and the formulation of laws pertaining to the physical world exerted a profound influence upon men's ideas in other realms of thought. Was man, the creation of

God, not as much a part of and as subject to an ordered universe as the physical earth on which he had his setting? Principles of human action of universal applicability were sought—and they were in due course conceived, if not discovered in any scientific sense. Blackstone, for example, contended that there had been established by the Creator a simple system of natural law or ethics and that "the constitution and frame of humanity" had been so contrived that if we but pursued our own "true and substantial happiness" we could not fail to be in tune with the universe of nature. Moreover, each of us in pursuing and achieving his own happiness unwittingly but inescapably promotes the happiness and well-being of his fellow men.

Oppressed by the restrictions upon individual freedom which characterized the eighteenth century, Rousseau declared all social institutions vicious in their effects upon free-born man—stifling everything natural in him and giving him nothing in return. "Civilized man is born, lives, dies in a state of slavery. At his birth he is sewed in swaddling clothes; at his death he is nailed in a coffin; as long as he preserves the human form he is fettered by our institutions." Said William Godwin: "Reason is the only legislator, and her decrees are irrevocable and uniform. The functions of society extend not to the making, but the interpreting of law; it can not decree; it can only declare

¹ Addressee at the conference of universities sponsored by New York University and held at the Waldorf-Astoria on November 15, 16 and 17, 1932.

that which the nature of things has already decreed."

In the light of these conceptions of natural law the functions of government were reduced to the simplest terms. At the most the state should seek to suppress or redress wrongs against individuals and to provide for common defense against foreign foes. The greatest merit of this reasoning lies in its emphasis upon the life of the individual citizen. The focal point of interest is human beings, and the goal is the unleashing of individual energies to the end that we who inhabit the earth may realize our potentialities in fullest measure.

Although the ideal of individual freedom from the so-called tyranny of government was never fully realized, under the influence of this conception of natural law, universal and unchanging in character, the very foundations of government throughout much of the western world were profoundly modified. Innumerable laws, inimical to the freedom and to the initiative of the individual, were repealed, and industry and trade were relieved from a multitude of hampering regulations. International relations were also profoundly influenced by the removal of restrictions against the international movement of trade and specie and against the migration of people from country to country.

While the remarkable changes in economic organization during the last half century or so have greatly affected our ideas as to the rôle which government must inevitably play under modern conditions, the traditional philosophy on which we have been reared continues to dominate our thinking. The crystallization, during the past few generations, of these conceptions—both of government and of the economic world with which government is primarily concerned—has tended greatly to restrict our mental horizons and to render us far from scientific in outlook. At the most, the

philosophy of government which we are discussing has been in actual application for only a brief interval of time and then in but a portion of the world. Political science, if it is to be animated by the spirit of science, must be limited neither by the calendar nor by geography; it must be timeless and spaceless, embracing within its domain the experience of all countries and all epochs.

Over a substantial part of the world, even during the eighteenth and nineteenth centuries, and over most of the world throughout recorded history, a view of the rôle of government other than the passive one which we have been considering has prevailed. This is the conception of the state as an active instrumentality in economic and social development. The government, whether monarch or parliament, under this theory seeks to direct and foster economic activity, or even to organize and control economic enterprise.

In the feudal era, to go no farther back in history, all society was organized and directed from above. The government, that is, the king, was supreme, and he ruled the people in the interests of what seemed to himself desirable ends. Vassals and villeins were servants of the lord and king and exchanged fealty for protection. Free enterprise, as we know it, was unknown—the entire economic system being organized from the center out. This same philosophy was paralleled in the development of church polity and canon law.

After the passing of feudalism, the conception of government as an active directing agency in the control of economic development remained over a large part of the civilized world. Aside from the countries of Western Europe and their colonial offshoots—for reasons already indicated—and from China and India—for other reasons—the govern-

ment has continued to play a very active rôle in economic affairs. In varying degrees, in Russia, Turkey and the Balkans, in Central and Southern Europe, in South America and in Japan, the function of government as an active directing agency has never been abandoned to anything like the extent that it was given up in Western Europe under the influence of the natural law philosophy.

The founders of modern Japan, for example, were nation planners and builders in as true a sense as are any of their modern prototypes. They set up a series of national objectives and then proceeded in systematic fashion to develop the ways and means for reaching these objectives. It was thought necessary to develop railway, telegraph, telephone and postal services; to stimulate shipping; to foster industrial development; and to promote the more effective utilization of natural resources, including agriculture, forestry, mining and fisheries. In carrying out this program of national economic development, the central government played a rôle of primary importance—such government leadership being consistent with, and the natural growth of, the principles of feudal organization which existed in Japan until 1872. There was here no tradition that the rôle of government in economic activity should be a passive one, with reliance upon private enterprise to furnish the drive required for progress. If economic progress were to come and come quickly, it was assumed as a matter of course that the government would have to set the pace. The Japanese system has remained essentially one of state socialism.

Similarly, the government of Germany has exerted a profound influence over the direction and character of economic development. This has been accomplished by means of the control of transportation, by subsidies to shipping, by systematic encouragement to agricul-

ture, by protective and other commercial policies, and by the mobilization of financial resources for the furthering of national objectives.

In recent years, governments everywhere have been rapidly extending the scope of their activities in connection with economic and social affairs. In Russia, state direction assumes one extreme form, and in Italy another. Elsewhere in Europe we find that the influence of government over business is being constantly extended, and that new government agencies in the form of economic councils of one type or another are being set up for the purpose of co-ordinating and guiding the economic life of the nation.

Even in the United States, the government has come more and more to influence and control economic activities in the light of what are regarded as wise national policies. The avowed purpose of the tariff and other commercial policies has been to develop within this country a more diversified and many-sided economic life than might otherwise have existed and to give to the American people a standard of living which, it is contended, could not otherwise have been realized. We utilize hundreds of millions of dollars of public money in developing ocean shipping and certain forms of internal transportation, the government even engaging in the operation of barge lines on the Mississippi for the ostensible purpose of demonstrating to hesitant private enterprise that it has here overlooked a golden opportunity. We spend other hundreds of millions of taxpayers' money in the attempt to overcome economic forces as related to agriculture. We seek to foster export trade by means of the promotional services of government departments and by special legislation. In various social ways, also, the government seeks to protect as well as to promote the welfare of the people.

It is, however, in time of national

crisis that the power of the government is invoked most actively in the furtherance of business enterprise. In the last three years, for example, people everywhere have looked to the government as the only agency that might restore prosperity to distressed industries and employment to the people. It has, moreover, been deemed necessary, even by a political party which extols most highly the principle of individual initiative and unrestricted private enterprise as the foundation of American progress, to utilize the financial resources and the credit of the government as a means of preventing the disintegration of the entire financial system.

It is evident that, in the western world, the cycle of time has brought us back pretty soon to where we were in the heyday of mercantilism. Whether we like it or not, we are having in increasing measure with each passing year an extension of the rôle of government in organizing and directing economic activities. If we accept the fact that throughout the world government does and inevitably must play a significant rôle in economic and social development, we are challenged at once by one fundamental question, namely: What will be the ultimate consequences upon the lives of individuals? Will such a system in the long run generate those creative influences which are essential to social development? Will each and every individual be able to realize his potentialities as well in a society in which the government plays a rôle of supreme importance? These questions are as pertinent now as they were in the time of Blackstone and Adam Smith. This issue is the fundamental one in the Russian and Italian experiments.

A large measure of government participation in economic and social development does not, it seems to me, necessarily mean that the development of the

individual will be arrested. Everything depends upon whether the government is autocratic in character or democratic, in its organization and in its methods of operation, and whether the objective of enriching human life is borne consistently in mind. It may well be possible so to organize our government machinery and so to enlist the interests of citizens in the affairs of their government—national, state and local—as to stimulate the development of individual capacities in ways and to a degree hitherto undreamed.

I think it may safely be asserted that on the whole the professional political scientists of the universities have contributed relatively little to the development of instrumentalities of government—most of our political principles and our governmental organization and procedure emanating from constitutional conventions or legislative bodies. The primary reason for this is that the political scientist has until very recently been under the spell of the eighteenth century. He has been interested chiefly in discussing the evolution of political literature and in describing the structure of existing governments. The fact that much the same charge may be made against the professional economist does not alter the truth of my contention about the political scientist. There has been almost no attempt on the part of professional students to reappraise the possibilities of government as an agency of social progress or to determine whether our existing government organization and agencies are performing with reasonable efficiency the functions which they are supposed to perform.

If we are to make significant contributions in this direction, it is essential that the work of university departments of economics and government be closely coordinated. The need of close cooperation here is much greater than between other divisions of the social sciences.

In the laissez-faire era, economics was not in any way concerned with government; it was merely an analysis of the working of economic forces under conditions of unrestricted competition, and political science was concerned with the divisibility of sovereignty rather than with the control of public service corporations. As conditions have changed, it is true that both economists and political scientists have become increasingly aware of and interested in the manifold interrelations of government and economic enterprise to-day, but they have in no sense joined forces in grappling with these problems. By virtue of their restricted training, both the economists and political scientists are seriously handicapped in analyzing any of the complex problems relating to government control of economic activities. The economist does not know enough about governmental organization and the political scientist does not know enough about business and economics for either to function with genuine effectiveness.

The experience of government departments and bureaus, of business organizations and of research agencies, alike, indicates that the vital need is for men more broadly trained than those of our generation in the related problems of government and industry. I submit that the desired result can not be obtained merely by giving a graduate student of political science a number of courses in economics, and vice versa. There must be a new and frontal attack made by departments of economics and government jointly on the problems in hand. Gradually, the entire curriculum of these departments must be organized around a common objective. Only thus shall the work of present scholars be given the greatest vitality, and only thus will we secure the type of future scholar and statesman which is required if the complex economic and govern-

ment organization of our day is to be effectively utilized in the service of society. Here in this field of training lie, perhaps, the most distinctive opportunity and the greatest responsibility of the university in relation to the changing problems of government.

The opportunity for fruitful research in the problems of government has never before been comparable with that which exists to-day. Time permits but the barest mention of some of the more important problems awaiting scientific study.

First, I would suggest a reappraisal of our comprehensive system of federal, state and local governments, and their interrelations. This general plan of government, and the allocation of functions and responsibilities which it carries, was established 150 years ago by men who naturally thought in terms of conditions existing in their day. It was before the age of railways, almost before the era of interstate commerce. Such industry as existed was organized and financed locally, and there was nothing resembling a national banking or credit structure. The principal public utility apart from the stage-coach was the town pump. Inevitably, the embattled farmers of 1789 thought of government primarily in local terms, with the state the largest unit necessary for almost any purpose other than the common defense. The size of the intermediate county as an administrative unit was determined by the limitations of horse-and-buggy locomotion.

Under the conditions of to-day, this system is in many respects no longer defensible. It results in no end of conflicting policies and regulations, it is extremely expensive, and it retards economic and social progress. Accordingly, there is imperatively required a reintegration of this entire system. The new division of functions and the changed relationships required can not

be determined by any arbitrary formula for national, state or local standardization. They must be worked out in the light of a coordinated series of studies bearing upon the various issues involved. We must seek to ascertain what types of problem by their inherent nature require federal regulation or control. What ones lend themselves most naturally to regulation by the state? What ones (bearing in mind the ultimate objective of enriching the life of the people) may best be dealt with by the various local governments? The question must also be squarely faced whether some of the numerous administrative units which have been handed down to us are required under modern conditions.

Second, in the particular domain of the national government we need—in addition to studies directed toward promoting economy and efficiency—a reconsideration in the light of present conditions of certain basic problems of government organization and procedure. Mention may be made of the system of party government; the division of powers and the principle of checks and balances; legislative organization and procedure; the administration of justice; and the functioning of independent and quasi-independent commissions, many of which have been shouldered with both administrative and judicial functions and are so overwhelmed by a multitude of detailed issues that they are unable to fulfil the major purposes for which they were created. Among the various departments and bureaus of the government there is not only much overlapping of function, there is also working at cross purposes. Reorganization is required not only for purposes of economy but quite as much in the interests of carrying out coordinated and consistent national policies.

In the field of the state, the entire governmental system, typically speak-

ing, needs overhauling, including in many cases a revision of the Constitution itself. Economies of great practical importance can be, and in some cases are being, realized through fiscal reforms and the establishment of adequate systems of financial control. Equally important results can be obtained through the reorganization of state government departments and agencies and the articulation of their activities in relation to a series of major state objectives. The time is ripe, at least in a number of states, for fundamental studies of the interrelations between state and local government and the economic, social and educational problems with which the people are so vitally concerned.

It is on the basis of studies such as these, and on this basis alone, that the economies in government expenditure now so urgently required can be intelligently made. Hysterical demands for economy by a tax-desperate electorate may easily become mere parsimony and result in crippling basically important state services, including education. Unless perchance there is substantial improvement in general economic conditions in the relatively near future, we must view the financial problem of state and local governments with keen apprehension. There is here a great immediate opportunity for the universities, particularly the state universities, to render practical, constructive service of great importance. Fortunately, in a number of cases the opportunity for such service has been embraced, by private as well as by state institutions. Aside from the benefits which may accrue to the state, such studies yield large dividends to science by bringing scholars into intimate contact with the real problems of government—by providing them laboratories in which to work. Those who pin their faith to the lonely thinker, working in isolation far from the busy

marts of trade or the arena of politics, seem to me to ignore the fact that it is just as necessary for the social scientist to check his thinking by laboratory observation or experiment as it is for the physicist or biologist. The laboratory of the social scientist is the world of business and government and social relations. The great contributors in social science have been those whose thinking has the touch of reality because they have drawn heavily from the lessons of human experience.

Third, it is necessary for us to take stock of certain principles, procedures and devices which have been developed in recent years with a view to enabling the public to participate more extensively, more intelligently and more directly in the processes of government. I refer to such varied expedients as the direct primary, short ballot, and the initiative, referendum and recall. We need to know whether the direct primary has resulted in giving us a better type of public official; what has been its effect upon the executive's power of leadership in legislation; whether it has scattered party responsibility and destroyed party discipline, and if so whether there are compensating advantages. With reference to the initiative and referendum, we need an appraisal of the effects of such measures not only upon the character of legislation, but also upon the people's attitude toward, and interest in self-government.

We have accumulated a wealth of experience on all these problems, but as yet there has been no systematic attempt to appraise objectively the actual results achieved. Here and there special studies are made of some particular aspect of this problem of popular government or of its success or failure in some particular jurisdiction, but we have had nothing like a general appraisal of these instrumentalities and devices.

Similarly, we have thus far given sur-

prisingly little attention to the experience of foreign countries with various devices and agencies of government. In books on comparative government we find detailed descriptions of the structure of different government systems; but there has been little study of the relative merits of alternative methods or devices for accomplishing given ends. What, for example, are the advantages, if any, of the system of administrative courts developed in various European countries, and could such courts be readily adapted to American conditions? What are the merits, if any, of the European system of delegated legislation? What light does the experience of other countries throw upon the problems of government ownership or regulation of various types of public utilities, and the utilization and conservation of natural resources? What light does the British and Japanese experience, for example, in the centralized financial administration of local units of government throw upon the American system of administering local finances?

In the light of this brief outline of the nature of the changing problems of government with which we are concerned, I should like to close with a few comments as to the magnitude and character of the research problem that is presented. I have already laid emphasis upon the necessity, in connection with many of these problems, of utilizing men with specialized training in more than one division of the social sciences. I wish now to stress the necessity of a concerted attack upon the problems before us. So rapid has been the pace of technological progress and so extensive and complex have been the resultant changes in the problems of government that a cooperative program of research has become a primary necessity if our investigations are to be of other than historical interest.

In some cases, this cooperation might

be worked out in terms of functional division of labor—individuals from one institution concentrating on one phase of a problem and those from another on a different phase; while in other cases cooperation should be developed on a geographical basis. Such problems as the direct primary, the initiative and the referendum have been experimented with in a score or more of states. It would seem to be the part of wisdom to enlist the interest of a group of institutions or individual scholars located in different parts of the country in making a united attack upon such problems as these. The objectives and the methods of the study could be determined in

joint conference; the experience of each state could advantageously be studied by a scholar resident within that state; and the results of the series of studies could finally be subjected to a joint appraisal by the various collaborators. The results of such comprehensive investigations might well be accepted by the public as conclusive in character.

That such cooperative research presents difficulties is readily apparent. But if we are to discharge the responsibilities which our training and the financial support accorded by our institutions impose upon us, we will resolutely face these difficulties and endeavor to overcome them.

OUR UNIVERSITIES IN AN UNSETTLED WORLD

By THOMAS W. LAMONT

J. P. MORGAN AND COMPANY

INASMUCH as this is an academic gathering, let us first consider what a shocking series of world events has been spread before the innocent gaze of our American youths who, born at the outbreak of the great war in 1914, entered only last September the portals of New York University and our other colleges.

For the first four and a half years of the childhood of this freshman of to-day he would have witnessed a world given over to wholesale slaughter. In that conflict were killed thirteen million able-bodied men. Twenty million more of them were disabled. Disease, privation and destitution accounted for the loss of six or seven million of civilians. There was a total of perhaps forty million people put out of constructive endeavor. In a material way thirty billion dollars of property were wiped out. In national debts an increase from about twenty-eight billion dollars to two hundred and twelve billion dollars—a terrible mill-

stone around the necks of the burdened populations.

At the age of five this American boy would have seen in the Versailles Treaty new states set up on uneconomic lines; a militant peace filled with resentments and the seeds of new misunderstandings.

THE STRUGGLE OVER REPARATIONS

And then that boy, from the age of five until now when he is eighteen, would have gazed upon an economic warfare waged in Europe, more destructive to commerce, to stability and to an ordered life than the great war itself. That phase will be known in history as the struggle waged over German reparations, a conflict that helped to bring Europe to the verge of general bankruptcy, ending only with the notable agreements reached at Lausanne last June.

During all those earlier years from 1919 to 1925, or beyond, this innocent youth of ours would have witnessed

(alongside the conflict over reparations) the pathetic and heroic endeavors of mankind to reconstruct a shattered world. He would have seen the piece-meal efforts by which Austria, Hungary, Bulgaria, Greece and other countries were set upon their tottering feet; and by which Germany, after complete debacle of the currency, had been reestablished under the Dawes plan. Other countries were slowly toiling back to the gold standard—Great Britain in 1925, France in 1927 and 1928, Japan in 1930. And again our sub-freshman would have been shocked to see the most powerful of these countries, Great Britain, only last year driven to abandon once more the gold standard; and since then forty other countries of the world either follow her example or place embargoes on the shipment of gold.

Meanwhile, as to politics, in almost every country radical changes of government were taking place. "The old order changeth, yielding place to new." Kings and hereditary potentates went almost completely out of fashion. On the continent of Europe revolutions were not infrequent, and in South America they became the order of the day.

And during all these years this American youth of ours would have witnessed other phenomena of almost equal portent. He would have seen the fantastic attempt by many nations to peg the prices of commodities—wheat, cotton, silk, rubber, coffee and a dozen others. He would have seen the unbalancing of government budgets on a wholesale scale and the fatal resort to inflation of the currencies.

INCREASING WAR BUDGETS AND TAXATION

What came next? The increase of war budgets of the leading nations. Instead of diminishing with the reduced national incomes, these budgets increased by 1931 to 65 per cent. above the average figures for the five years preceding the Great

War. The burden of taxation in almost every civilized country, including our own, has become increasingly and intolerably heavy. Our eager youth would have seen tariff barriers built up on every side, with our own country in the lead—barriers which all over the world prevent that very exchange of goods and facility of commerce which are essential to the restoration of world prosperity. He would have gazed at those great stores of gold, shipped clumsily and extravagantly back and forth across the ocean; a total in the last four years alone of almost four billions of dollars in and out of this country.

There is another phenomenon of the times which has rapidly and alarmingly developed. That is the growth of an intense nationalism in every part of the world. Almost every separate people has sought to shrink within itself; to dig itself into its own cyclone cellar and endeavor to save itself, come what might to the rest of the world.

Yet despite that reparations warfare that was going on in Europe for thirteen years; despite all those artificial barriers that were being raised against world recovery; here in America under the early stimulus created by the war's wholesale destruction of goods we were beginning, during the middle years of this last decade, to enjoy a singular prosperity. Our factories had been stimulated by the wartime demand from overseas for our goods. There came to be plenty of work for almost every one and plenty of people to buy. There was a brief recession of business in 1920 and 1921. Many persons believed erroneously that it had been sufficient to liquidate fully the economic effects of the war. At any rate, America's natural resources, intense energy and resourcefulness again came to the front and created the beginnings of our boom times.

OUR FOREIGN TRADE POLICIES

Acting, however, upon a deliberately

adopted national policy, we tried to buy as little as possible from the foreigner. But we were keen to sell him our goods. So in order to sell him, we proceeded to lend him the money wherewith to pay us. From 1922 to 1929 American investors and institutions lent abroad approximately six billion dollars net. American banks and bankers have been sweepingly criticized for arranging such loans. In certain cases criticism as to lack of care in investigation and method has undoubtedly been justified. But the general movement was a natural one, forced on the investment community by reason of our national policy of buying abroad as little as we can, and of attempting to force on the foreigners all the goods we can possibly sell them.

Thus during those years from 1923 to 1929 the American community proceeded to complete what seemed like the charmed circle, and then began to make it whirl. The formula was a simple one: The more money we lend to the foreigners, the more of our goods they will buy. The more they buy, the more we shall manufacture. The greater the demand becomes, the more we expand our factories and equipment. The more we manufacture, the higher prices go. The higher prices go, the higher wages rise. The higher wages are, the greater becomes the public's purchasing power. Everybody has a job. Millions of dollars paid in salaries and wages are put to newfound uses; quicker ways of transportation; delightful means of communication; all sorts of alluring devices; most of them tending to increase the material satisfactions of life, but not leaving a sufficiently large proportion of savings laid by for the rainy days. And for the workingman it has rained almost steadily for the last three years.

THE GREAT SPECULATIVE ORGY

Then, starting about 1925, from small beginnings came the grand American speculation. Our people from one coast

to the other were seized with a desire to get something out of nothing. They did not want to invest for income. They wanted to buy for profit. Speculation spread in commodities, jewels, real estate and securities. For a while it all seemed so easy. Stocks go up on the stimulus of purchases. The higher they go, the more new purchasers come in. The more fresh buyers there are, the higher the stocks go. It is a great and exciting game—jumping on this endless-chain escalator, constantly going faster and higher.

Then came the collapse from prosperity, a change in this country after a few short months to days of depression, deflation, failure and, in so many instances, of despair. Just as a side-show, we display to these young people of ours other phenomena—shaky banks, failing banks, hoarding of gold—all the outward evidences of panic. This was as recently as a short year ago and less, although now that phase is fortunately at an end and confidence is restored.

Those, then, are some of the pictures spread before the guileless eyes of our American freshmen who have never been privileged to see anything of a world that we elders would term normal—those youths from the age of nine to fifteen looking out upon a seeming world of domestic prosperity and gladness, and then from fifteen to eighteen watching millions of people walk the streets looking for jobs, demanding the shelter and food which must be furnished to them.

A RETURN TO CONSTRUCTIVE EFFORT

But let us now turn to the other side of the picture. The panic of fear has subsided. Normal processes get under way. Gradually we see again the genius of the American people come to the fore. Efforts, systematic and gigantic, have been started and are now beginning to work. Almost the whole community seems banded together, determined, first of all, each man to help his fellow; de-

terminated that no one shall perish from lack of food or shelter. Manifestly, and with renewed confidence on all sides, men are exerting their best efforts towards reconstruction. Government co-operation has come in upon a grand scale and in a score of different ways. Things gradually begin to straighten themselves out. The deflation of commodities seems almost at an end. Hard work begins to fill up the gaps. The fingers of a new dawn stretch their tips above the horizon. There are signs of betterment decidedly more tangible than mere hope.

In the midst of our efforts for avoiding shipwreck, for saving those already on the rocks, we hardly have had time to study whence the storm came. Yet questionings have already begun on an active scale. Each one of us is looking around for a scapegoat. Why do my pet investments which paid me 6 per cent. go down in price from 150 to 15 and now pay me no return? Was it the fault of the broker or banker? He answers: "No, we may have been no wiser than anybody else. But certainly the chief loss has been due to the severity of the depression which has caused heavy depreciation in the soundest of American investment securities."

GOVERNMENTAL EXTRAVAGANCES

Is our trouble due to government extravagance? In a certain measure, yes. Money was being spent so freely, taxes were being collected so rapidly that all our governmental bodies fell into the easy habit of spending money like water. New York City's funded debt has grown in ten years from eleven hundred million dollars to eighteen hundred million dollars. Its annual budget has increased in the last ten years from three hundred and thirty million dollars to six hundred and thirty-one million dollars. As to the Federal Government, with the budget out of balance, the Congress has very properly been obliged to levy heavy new

taxes, adding to the serious burden of taxation that had been arranged on a generous scale when there was ample income to pay the bills.

Others of us have another alibi. We have found a scapegoat which can not kick back. It is the devilish foreigner who has done all this to us. He got into a frightful mess and hauled us into it. He borrowed our money and then went bankrupt, or almost bankrupt, and a good part of the loss he has never paid back. He fell into a panic in Central Europe, and the panic, like a prairie fire, jumped over here. This is a difficult alibi to sustain, by reason of the fact that Europe's crisis in the spring of 1931 came eighteen months after the American collapse of October, 1929.

THE WAR DEBTS A FACTOR

Other people have found still a different scapegoat, the anatomy of which is well worth examining: It is Congress, and behind Congress the American people, which for years has insisted upon the foreign governments paying us the perfectly just—perfectly just, I say—but impossible war debts. We have held to the idea that these great overseas payments, representing in general nothing except exploded shot and shell, shall be paid every year—a quarter of a billion dollars each year—an unnatural stream of payments, choking the channels of world trade.

Incidentally, it was perfectly reasonable that the Allied powers should expect and demand that Germany should pay sufficient to repair the physical damage wrought by her armies in Belgium and northern France. But the bill has not been paid in full, nor can it ever be so paid. Similarly, people are asking: will it ever be possible for the unwieldy war debts—undertaken no doubt with reasonable expectation on both sides that they would be discharged—ever to be paid in full at Washington?

These, then, have been some of the

phenomena which world civilization has presented to the wondering eyes of our youth for the first third of the twentieth century. My purpose has not been to discourage you, but just for a few minutes to let this vivid panorama unfold itself before your eyes. To our elder view, accustomed to the various ups and down of this life, having seen former panics and former depressions, the spectacle, terrible and prolonged as it has been, is perhaps not quite so startling as it would be to the inhabitants of another world.

We can lay our difficulties at the door of no one person; no one group of persons; no one government. The greatest, single underlying world-shaking cause of the depression has been the war, its prodigious losses, its repercussions, its dislocations, its unsettlement of morale, including speculative orgies—war and the unwisdom of man who permitted that war.

VARIOUS POLITICAL IDEAS

What is the remedy for the world's present situation? Many among us, without adequate regard for some of these manifest causes of the depression, are declaring that the whole economic system of civilization has broken down once and for all and should be thrown into the discard. Is then the answer to be a grand leap into Socialism? Or a somersault into Communism? My answer is "no." Before we move in this direction we can well afford to observe and profit by other people's mistakes, or perchance by their successes.

Is the remedy one great plan of economic organization, something that will surely balance world-wide production and consumption to a nicely and always provide work for every one? That is the Utopia that the world may work towards. But there is no swift and royal road to universal prosperity. We have to rely not on gods, but on men, to devise, plan, organize and execute. And we must rely

upon them with their limitations. In general terms, we can say that the American economic community has done far more extensive planning than it ever did forty years, or twenty years ago. We have seen, however, how far it has fallen short. Yet that does not mean that, while in the modern world we may well have come to a turning, we have come to the end of the road.

NOT REVOLUTION BUT EVOLUTION

No, I am one who believes that we must rebuild on the basis that is still under us. We must, in Mr. Lippman's phrase, continue to live in the house while we are rebuilding it. You may call that house, if you will, the capitalistic system. It has been in the building since the Dark Ages. It has, with all its ups and downs, brought to mankind increasing comfort and happiness. It is still a fairly tough structure and will not easily topple over. But it has developed some serious weaknesses which require more than patchwork attention.

WHY THE YOUNGER GENERATION IS RADICAL

Realization of that fact brings us back to these universities of ours. I hear complaint that our college professors are teaching too much of socialistic theory. That would not be my observation. These are days when among the teaching forces of our institutions the freest sort of academic freedom should prevail. But to me it is little wonder that many of our students to-day are radical, are joining the Socialist party or are even looking with a kindly eye upon the allurements of Communism. The sort of world that they have seen is the one of chaos that I have described. They know no other. The modern world that existed prior to 1914 is as unreal to them as the age of chivalry is to us. In a world of flux they want something that they can cling to, hold fast to. And they eagerly embrace what seems to

them the solid faiths which assume to have solved all our questions.

It is the growth of science that is perhaps the most encouraging single feature of our modern civilization, going far to offset its present failures. The discoveries of science are, as we all know, constantly tending to strengthen and prolong life. The luxuries which science creates give us, in turn, time for more science. We see on every side scientific discoveries (I am not alluding primarily to mechanical development) being made by men studying purely for science' sake; workers going on quietly and steadily in their laboratories, regardless of a changed or broken world.

If, then, a purely man of affairs can presume to speak on an academic subject; if thus I were to make a plea to our universities—to both students and teachers—it would be to set up the scientific method as a goal to almost every end. In training the mind of our youth, in teaching the student to think and to use his mind as he would a finely tempered tool, we should urge always the practice of the scientific method. That method proceeds by experimentation, by making a disinterested search for truth, by getting the facts and seeing where they lead. Imagination constructs the hypothesis. Then we verify or check the hypothesis to see if the thing works.

THE MAINTENANCE OF AN OPEN MIND

This means that no fixed and static dogmas can necessarily stand unchanged in a changing world. They must give way to fit the altered conditions. Our university can give the student the spirit of this scientific approach to most efforts of human endeavor; not only to the realm of abstract knowledge, but to a vast number of the practical affairs of every-day life, to sociology, religion, business, politics, government. Our university can give its students tolerance, so that they will not condemn an idea off-

hand, because it is new or because it is old. It can help them to develop that tempered judgment which is the beginning of wisdom.

And as I would urge the scientific method upon teachers and upon these new students of ours, just on the threshold of the university, so would I urge upon myself and upon my associates in the world of affairs to turn away from every form of bias; to examine with unprejudiced eye any new economic system or change of our present system that may be proposed; above all, to get away from that rigid nationalism which has proved so crippling.

THE FOLLY OF ECONOMIC WARS

But I beg you will be under no illusion as to my own individual convictions, unimportant as they are: No economic system whatever—old or new—can be devised which shall be proof against the folly which mankind has shown. In 1914 to 1918 white men engaged in a titanic struggle of self-destruction. It was the first war of populations. Previous wars had been wars of champions. In the great war the whole economic power of the populations of the countries engaged was enlisted.

When the war ended the statesmanship which led the world was exhausted, neurotic and embittered; with the consequence that the treaties of peace brought no peace, but erected fantastic new barriers to peace, political and economic. Unwarranted frontier changes, and anomalies like the astronomical reparations claim, left bleeding wounds in the body of mankind. Looking back we now see that it was inevitable from these peace settlements, which were no settlements that the war should not stop but should be transferred, as it has indeed been, from the military to the economic field. Here America has been one of the leaders in the economic war. In the two drastic tariff increases of 1922 and of 1930 she set standards for the

strangulation of trade which other weaker nations felt compelled to emulate. Thus, the four years' war on the battle fields of France has, as I have already pointed out, been continued by a fourteen years' economic war on a world-wide front.

THE WORLD'S INTERDEPENDENCE

Remember, after all, that we are in a world of men who, all over the globe are singularly alike in their passions and prejudices. Just as we have seen this depression to be world-wide, so every country is dependent in part on the misery or the good fortune of every other

country. Even America, with all her magnificent resources, can never be wholly self-contained.

Remember, again, that we are now on the threshold of a new stage of progress and that America must lead the way. It can go far on that way only by realizing that it is a part of the world; that the world also must move with it to new recoveries and new stabilities. Our primary remedy for present difficulties is not in the change of economic systems. It consists in an enlightened public opinion which will demand of our rulers that they seek peace, economic as well as political, and pursue it.

SPRING DAYS IN ZUNI, NEW MEXICO

By Dr. ELSIE CLEWS PARSONS

HARRISON, NEW YORK

WE motored in from Gallup over the new road, in two hours. Twenty years ago I once made the trip in a wagon in eight hours, by the old road, which is five or six miles shorter; but that day snow was deep on the ground, and more was falling and it was so cold that the lips of the Governor were blue until I broke the excise law and gave him a drink from my flask. That was before prohibition for Whites, but not for Indians, and the week before, Shalako night, I had gone around with him and the Farmer as they confiscated the white mule, a hundred bottles or more, from the visiting Navaho. But a snow-storm makes its own conditions, and I knew the Governor had become a staunch prohibitionist, as were all the Pueblos just at that time—they are not to-day.

This year even the new road had been passable for only two weeks, because of the great snows of the winter when food had been dropped from aeroplanes for the marooned Navaho and a Zuñi perished on his way back from picking piñons in the mountains. In October a party of Zuñis had visited the Hopi to dance Kachina, and the devastating snow-storms were imputed to their rain or snow making dance—it had been too successful.

The dance-visit had been suggested by the new Kopekwin, the son of a Zuñi-Hopi father. It was from his father, no doubt, that the Kopekwin had heard of the old custom of visiting the Hopi in late autumn to dance Kachina. The custom had lapsed since the close of the last century.

I asked the Kopekwin when the next initiation of the boys into the Kachina society was to occur. A year ago, in the spring of 1931, the last initiation took

place; one hundred and twenty-five boys were initiated; one of the six kiva groups, Hekiapakwe, which had been much depleted, was again vigorous, much to the satisfaction of the entire pueblo. He did not know about the initiation date, answered the Kopekwin, he had much on his mind—he, more than any one else, determines the year's dance program. Besides, he was worrying about the future of his fraternity, the Shi'wannakwe. The Shi'wannakwe is the "oldest" of the thirteen fraternities or curing societies of Zuñi. Its chief has to be a member of the Badger clan and of a particular maternal family within the clan. Now the only one in the Kopekwin's family who could qualify for the position was his own brother and he was not a member of the Shi'wannakwe fraternity.

The Kopekwin was also disturbed about one of the houses in which a ceremonial group is to be entertained at the next Shalako or Advent of the Kachina, the masked dancers. In late November or early December eight new houses or rooms are "blessed" by impersonations of the Spirits or Kachina, who bury prayer-sticks below the earthen floor. The householder who had volunteered to entertain the Sayatasha group was in bad repute. She was a Laguna woman married into Zuñi—many times—and the last time she had entertained the Sayatasha group, gossip had it that she had sold the prayer-sticks from under her floor. Perhaps she would do it again. Had the Kopekwin been in Zuñi at the time her husband went and got the stick of appointment, i.e., when her offer to entertain the Sayatasha was accepted, the Kopekwin would never have agreed to it. The Sayatasha group

consists of five impersonators. Two of them had refused to serve because of the scandal about their prospective hostess, and their places had to be filled by others.

A departmental row, dishonesty in office, failure of family successor, miscarriage in weather control which meant loss of crops (the corn could not be harvested until January and was partly spoiled), of sheep and of one human life —no wonder the Kopekwin was worried and looked it, as he sat there waiting idly for his meal. Because of his position he could not be asked to cut wood or do any of the chores a self-invited guest may be called upon to do.

There are still other matters the Kopekwin and all the older men of Zuñi have to worry about. The Laguna woman is not the only seller of ceremonial objects; the only ex-service man of Zuñi is said to be another and on such a scale that he can afford a car. "We do not know where he gets his money," is said of him, which is the pueblo way of saying, "we very much suspect he has been doing something he should not do." It is becoming increasingly difficult to get young men to impersonate the Shalako, one of the most exigent of the ceremonial rôles, for it is a year long devotion of visiting distant shrines and memorizing prayers. "The young men are lazy," commented a critical girl, a half-breed. "No, my dear," I rejoined, "they do not believe." "Do you believe the Sun will help you if you pray to him?" I asked the girl's brother, a leader in the Returned Students' Club. "No, I don't," said he. "And you don't believe in the White people's god, either, do you?" "No, I don't."

Over a hundred years ago the Franciscan Fathers departed from Zuñi, but within the last decade the mission has been reestablished and has been maintaining a school. At first the return of the Catholics was bitterly opposed by all, excepting a small group of towns-

people led by Jesús, a Yaqui Indian who had been captured as a child and sold into Zuñi. The girls would not come out to dance for the Saint, although the Saint had been cherished through the century as much as the other fetishes of the town. But the returned Fathers and black-habited Sisters whom the Zuñi call crows have been wise during these years; they have interfered little if at all with the older people, directing their attention to the children, working towards the future. The native hierarchy is unaware of Catholic or modern pedagogy, "give me a child up to the age of seven," implies for them neither threat nor promise; and as for the older children, have they not seen their children going to the school of the Reformed church mission for the last thirty years or so and still not a single convert in the town? So now the Catholic issue is in abeyance; it is not worrying the elders; Catholicism, like Protestantism, means merely more shoes or clothes, cakes and coffee Saturday night or on the Saints days which are not otherwise recognized in the native calendar. Nor does the psychological attitude of the youths back from the boarding-schools trouble the elders, as long as the youths are initiated and dance. Zuñi elders are ritualists, not philosophers, pretty much as were our own elders fifty years ago; as long as the young people "go to church" they are not questioned on what they think about it.

Being one of those wholly irrational persons who is not interested in religion for himself, but very much interested in religion for others, during this recent visit to Zuñi, I was beginning to worry, perhaps more than any Zuñi elder, about the town's irreligious tendencies. I was sorry to see two of the paramount priesthoods reduced in numbers—in the rain priesthood of the North or Town chieftaincy there are but two members, the Kiakwemosi Klashi has died; and

there are but two members in the war priesthood, Loco Joe, who was initiated in the last Scalp dance as Bow priest elder brother, and Tsawele; Hompikia died last summer (so this winter the Wood society had no ceremonies, it was Hompikia who used to lead them in), and Wayeku died two or three years ago. Tsawele's prestige has diminished since he was charged with witchcraft a few years ago in an attempt to reveal the magical cause of the dysentery from which the townspeople were suffering. After the actual witch had been caught one night trying to lie next to a woman to make her sick, he confessed, showing where he had buried his painted eggs, and he was subsequently banished, but in the public trial in Big plaza he threw suspicion upon his prosecutor, Tsawele, charging him with keeping certain feathers inside his moccasins. As for Loco Joe, now called Joe Crazy Horse, he acts as clown in the Gallup Indian show and more than once in Zuñi I caught some young men laughing at him to themselves. A war priest charged with the crime of all others from which he is counted upon to protect the town, and a war priest, the custodian of the mores, taking to vaudeville and ridiculed by the youth! What are we coming to!

Then there are less unexpected changes going on, to be deplored or not, according to one's point of view. The town is no longer compact; new houses have been built on all its outskirts, houses of dressed stone, instead of stone, mud chinked and plastered, or adobe, and some of the houses have peaked roofs. These changes in building of themselves necessitate changes in the ceremonial life. No longer can the Koyemshi dance from roof to roof singing the song of the mountain sheep, and domiciliary visits by any of the Kachina become less easy.

The first house of stone and with a peaked roof was built about fifteen

years ago, by a Cherokee mixed blood married into Zuñi. Two of the recent houses in this style belong to the offspring of Jesús, the Yaqui, to his son by another Yaqui captive, and to his daughter by a Navaho. Another stone house belongs to a woman from Isleta; the woman from Laguna has a stone house. Newcomers of course may have to build houses for themselves and naturally they build on the outskirts; but, practical conditions aside, newcomers tend more readily to innovations than do the old established families. In this connection I note that the single ex-service man is married to an Arapaho.

This marriage was made through boarding-school acquaintanceship. In all the Pueblos the boarding-schools have been a considerable factor in the mixed marriages of recent years; and these have been a factor in breaking down tribal culture, ever since the two Marmon brothers and another white man married into Laguna in the seventies. Mixed marriage and the wage system whereby the youth grow restive against communal service (the Black Rock dam broke the day before I reached Zuñi and the boys complained because they were not being paid for repairing it) and acquire American tastes and habits of expenditure, these two conditions of life are undermining native culture throughout the pueblos. Tourist traffic and vaudeville trips help too. On the wall of Mary's house hung a photograph of the "artists" who had visited Atlantic City—old acquaintances from Acoma, Taos and Zuñi, and some Navaho whom I did not know. All the Pueblo singers had in one way or another broken with their traditions and ceremonial obligations. Some were of mixed blood, but not all. Who knows what germs of cultural disintegration they had brought back from Atlantic City and elsewhere, even from Europe! Gloomy reflections!

Then the day before I was to leave,

Zuñi held a kick-stick race and all such reflections were dissipated into the air, as high as the kick-stick. Here at least was nothing to warrant apprehending that the culture was doomed to disappear, say within fifty years. Spring is the Zuñi season for foot racing, which opens with two ceremonial races, by kiva and by clan. One of these had been held on April 7, on the same day as the last dance of the spring dance season, which was Mosatechiwe, Hopi saint dancee. (Although the Hopi have no saints!) The race on April 16 was the first of the general series which would keep up until the Summer Solstice ceremony towards the close of June. This series is more or less in charge of the Sho'wekwe, an informal sort of group whose members know the ritual for the winter gambling games and the spring racing, also a form of gambling. Two Sho'wekwe, sometimes any two men, assemble the race teams of three, four or more members. Sometimes the team are all kinsmen, "like Oscar's bunch." Each team meets in the house of its manager the night before the race, with a Bow priest or a fraternity man to pray and sing and make food offerings to the War gods and to deceased racers. "They give food to the Earth," according to Frank, and, like Deer boy in the familiar Pueblo folktale, they ask the Sun not to beat down on them as they run. "White fellows rest before a race, but we stay up all night," remarked Jakey. During this night sound omens are sought, from birds or from the dead, as they used to be sought in war-time, on the eve of campaign. Sometimes a spy from the other side listens in to these omens; in view of the big bets made on the race advance information is valuable.

About 4:30 p. m. I went to Big plaza to see the betting. Three or four men representing each side advance in two rows to encounter each other in the middle of the plaza. Several carry bundles

of goods. These are what have been left over after the racers have made their bets in one of their houses of overnight retreat. These plaza stakes may be matched by bettors at large, and now several men carrying what they wish to put up join the central group. Blanket is matched with blanket and the two tied together, shawl with shawl, silk kerchief with kerchief, belt with belt. All the stakes appear to be wearing apparel, money is bet, but I think privately, and probably only by the younger men. Jakey had planned to bet privately the shirt off his back, an orange silk shirt his sister had just made him, but luckily for him as it turned out, his taker withdrew, and at the close of the day to the satisfaction of all of us he was still wearing his gay apparel, blue velveteen trousers as well as orange colored shirt.

The betting crowd was as quiet as Zuñi crowds ever are; the matching was done quickly and without dispute, no voice was raised, it was a smiling, cheerful party. It took them about an hour, then the piles of goods were left there on the ground and the crowd, on foot and on horseback, about two hundred men, moved across the river by the new bridge to the starting line on the road to the south.

Here we waited for the runners to appear after they had forded the river by the traditional crossing and had said their last prayers. Each team of four men was led single file by their overnight ceremonialist, in this case a Bow priest for one team, and an Ant fraternity man for the other. The leader cast a handful of prayer-meal in front of his team before he left them at the edge of town. With this rite he was "opening the road." The racers continued on, first the Itiwanna or Middle team, a few minutes later the Pathtok or East team,¹ into a stretch of greasewood

¹ Their manager was Has, son of Apah, and they had been in the house used by the Shuma'kwe fraternity. According to Stevenson, this fraternity has racing "medicine."

where they stooped to pray and sprinkle prayer meal. The team scattered, evidently each was praying on his own. Then in single file the runners came over to the starting line, the arms of each folded tightly across his bare chest, as if holding in something. As indeed they are, the powers of four swiftly flying birds—anethlauwa, hawk, shokya-pissa, red shoulder hawk, akwatsu'ta, ts'ewia—the same birds, at least some of them, the Hopi mention in their racing song:

Be racing.
With joyful words.
Be racing.
The abdomen, the back.
Hawk (Cooper's hawk, etc.)
Be racing.²

These powers for "abdomen and back" have been obtained during the ritual of the preceding night. It is an interesting illustration, by the way, of how the Plains Indian concept of getting power from the Spirits, personal power through personal experience, is transformed in Pueblo circles into power through ritual, for a group.

Our Zuñi racers wear kilts of nondescript cotton or woolen cloth; torso and legs are bare and they are barefoot. "They *have* to be barefoot," i.e., this is a ritual exigency. (The better to attract the attention and arouse the pity of the Spirits, the Hopi would say.) Itiwan have a white cotton *banda* around the head; Pathltok, one of blue silk. They all happen to be youngish men, from twenty-five to thirty-five, and their hair is short; but the locks on top are gathered together and tied with a string; inside this bunch of hair is concealed an arrow-point, in Pueblo circles ever a protective charm. Protection is needed, for black magic is practiced in these races. Cramps are caused by magic. Ned, one of the returned,

² H. R. Voth, "The Oraibi Powamu Ceremony," 152-153. Field Columbian Museum Pub. 61. Anthropol. ser., vol. iii, no. 2, 1901.

English-speaking students, is afraid to race this year because after remarkable success last year he became the victim of magic-induced cramps.

Itiwan arrive first and choose the west side to stand on—the road runs north and south, like the Tanoan race track, by the way. After Pathltok arrive, the two teams face each other and the leader of Itiwan, i.e., the team first to arrive, hands the two kick-sticks to the leader of Pathltok to choose his stick. Now Bow priest elder brother produces some red paint, the ordinary red face-paint, and both sides proceed to paint their stick. The Itiwan leader paints a red band around the center; the Pathltok leader, a red band around the center and a narrower band of red around each end. The sticks are about five inches long, of oak wood, decorticated. As we crowd in to watch and I peer under the big felt hats I notice that the Pathltok leader is blind in one eye and his mouth drawn to one side. He is saying something as he rubs his finger over his stick.

Usually the Bow priest throws the sticks, but this time the two race leaders throw and the race is on. Younger fellows in the crowd run on, whooping the Zuñi war cry—*tohálala! tohálala!* A man on a white horse takes the lead and will set the course, past Grease Hill, on towards the southern mesas, then towards Towa Yallane, "Corn Mountain," and back to the river ford, a run of about an hour and a quarter, seven or eight miles. The road is soon left and the country is rough going. The stick may not be touched with the hand, nor may it be held between the toes in extricating from crevice or brush.

After the start the house tops begin to fill up with spectators. This is the time bets are made between the men and the women. Frank and I go to the river bank to watch the runners come in. Others have gone out to meet them, so they return with the same whooping

crowd they started with. One of the four has dropped out, he will have been picked up by a horseman. The losing team does not finish; they, too, are picked up by their friends on horses. The stick is kicked high, perhaps twenty feet, well over the heads of the crowd, and the kicks I saw at start and finish covered short distances, not more than a hundred feet. The final kick is into the river. But the stick is retrieved and will be placed in an arroyo to be carried away by flood waters, thereby giving speed to the runners. (This information comes in half-breed, Americanized terms. I have no doubt that the sticks are deposited not to make the racers swift but to make swift floods. The Hopi term for racer is Desiring-flooded-arroyo. The Clouds will have seen the fastest runner and will be glad to listen to him, his prayers for rain will have special virtue.)

After crossing, the runners continue on to Big plaza, Frank tells me, run around the pile of bets and return to their house of retreat. Before the goods are moved from the plaza they are sprinkled with prayer-meal and again they are sprinkled in the house of retreat before the winners appropriate them. The people of the house give a big supper. For ritual reasons the runners have been given an emetic.

The losing team, Panch they are called, may reenforce themselves with two new runners. They may also go to two of the paramount rain-priesthoods, the priesthood of the South and the priesthood of the West, for greater power. And they, the Panch, set the date for the next race with their victors, also the course.

I wish I had seen more than the one race and more of that. I have since learned that this spring there have been fourteen more races, including several "bigger" races than the one I saw, involving a longer course and more ritual.

Even in the early race I surmise that there were rites I did not hear of, no doubt the leading runner "breathes from" the pile of goods which he circles in the plaza, and no doubt he deposits his kick-stick with prayer-meal the following morning after his hair has been washed.³ Nothing of importance ever occurs at Zuñi without hair washing.

My calendar-keeping friend has recorded a race every Sunday from April 17 to June 5, i.e., eight Sunday races with another race as a rule during the week, any day from Monday to Thursday. That Sunday should be thus observed indicates that the economic week is now recognized at Zuñi, a very significant change for those who not so long ago "counted their days" wholly by sun or moon. Not that they do not count so still. Three days after the last race on June 6, Sun priest called out that in eight days all were to plant their prayer-sticks for the Summer Solstice ceremony. Nothing of the Augustean calendar in this!

My Zuñi friend has done better by calendar dates than in explaining how the various teams—she mentions five teams and gives the names of forty-eight runners—are selected, nor does she name all the fraternities that made the racers ritually fit to run not only to win heavy stakes of material goods but to promote the rainfall which will affect the crops of all the townspeople.

There is still much to learn about the Zuñi kick-stick race, but incomplete as was my ethnographic information when I left the Pueblo, I left with lessened despondency. As long as men bet gaily, risk stone bruise or cactus wound whether for pleasure or for profit, and dread black magic, the spirit of old Zufii will live on, despite schools, wage system and foreign spouses.

³ See M. C. Stevenson, "The Zufii Indians," Twenty-third Annual Report Bureau American Ethnology, pp. 318-328. 1901-2.

SOME MAGNITUDES

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MODERN science is reaching out farther and farther into the distant corners of the macrocosmos and is likewise delving deeper and deeper into the intricate structure of the microcosmos. In this ever-widening frontier of exploration many quantities, large and small, are measured or calculated. Distances are recorded in light years in one branch of science, in Angström units in another; velocities are measured in kilometers per second and in millimeters per day; while other extremes of the measuring scale are tons and gammas, years and sigmas, atmospheres and dynes and many others more.

To compare some of these significant measurements by converting them into a common scale is the purpose of this paper. In the following tables an attempt is made to collect the most recent data showing the extremes as determined or reasonably calculated by the different branches of science. The task is interesting, for it reveals some rather interesting sidelights.

1. THE DIMENSION OF LENGTH

It is a curious fact that man is just about half-way between the largest and smallest object, for he is 10^{20} times smaller than the Milky Way in which he lives, and 10^{18} times larger than the proton out of which all matter is made. But the indications are that the Milky Way is not the largest, nor the protons the smallest object, and explorations in both directions are still unfinished.

Assuming that we have some conception of the distances existing upon our earth, we find that the diameter of this planet is about three times the air-line

distance from New York to San Francisco, while nine times that distance is needed to span the equator. If we travel eighty-seven times between these two cities, we have traveled the distance to our nearest neighbor, the moon. This satellite has a radius extending from New York to Denver and is, with our earth, only a mite in the universe. Nearly twice the distance from earth to moon is needed to arrive at the radius of the sun, hence the moon's orbit around the earth will find ample room to move within the sun. Distances increase rapidly when we measure the remoteness of the sun from us and other planets, yet the diameter of the solar system with its ten thousand million kilometers is but an insignificant fraction of a light year, the latter being nearly 947 times longer. To visualize these spans of space we may calculate the relative distances required for placing a football, nuts, peas and lentils to represent the solar system;—if the nearest star, Sirius, is to be represented by another football, placed at the proper distance, we shall have a demonstration of the reason why we can not observe any planets surrounding other stars, for the size of the solar system is insignificant compared to stellar distances. Yet the multitude of stars which we see on clear nights are but a small fraction of those which make up our galaxy or Milky Way system, the diameter of which has a reach of fifty-thousand light years, or ten times as much as the nearest star cluster. These are objects faintly visible to the eyes, but in the telescopes revealing themselves as accumulations of many stars, likewise at great distances from

each other. The space between our two footballs is large and if all other stars are relatively placed in such spans, our Milky Way system is mostly empty space. Yet beyond this galaxy there are thousands of other galaxies, spaced approximately at forty times their diameters, until we come to the farthest spiral nebula discernible by photographic means at a remoteness of a hundred forty million light years. Yet the end is not yet, for the range of man's calculation, the diameter of the Einstein universe, is fifteen times farther.

Turning in the other direction, we explore the nearness of the microcosmos and follow smaller and smaller particles into the realm of the microscope and the world of cells and nuclei and chromosomes. On the borderland of the visible we come to the domain of colloids and ultramicroscopic particles, and from this aggregation of molecules we pass to single molecules and to atoms. Dissecting the atom into protons and electrons we come to the smallest thing, at present—the nucleus of hydrogen. Magnifying electrons and protons to the size of a football and pea, and placing these at the relative distances from each other to represent the orbits of electrons, we find that these diameters and distances resemble in inverse proportion those of the starry universe and that matter is likewise—relatively empty space.

TABLE 1
MAGNITUDE IN LENGTH

Einstein universe	$2,000,000,000$ light yrs.	1.9×10^{28} m
Farthest spiral nebula	$140,000,000$	" " 1.3×10^{24} "
Galaxy to galaxy	$1,800,000$	" " 1.7×10^{22} "
Andromeda nebula	$900,000$	" " 8.5×10^{21} "
Milky Way diameter	$50,000$	" " 4.7×10^{20} "
Sirius from sun	8.9	" " 8.4×10^{19} "
1 parsec = 3.08×10^{11} km	.....	3.1×10^{14} "
1 light year = $9,462,700,000,000$ km	..	9.5×10^{16} "
Solar system diameter	$10,000,000,000$ km	.. 1×10^{17} "
Neptune from sun	$4,400,000,000$ km	.. 4.4×10^{17} "
Earth from sun	$149,000,000$ km	.. 1.5×10^{18} "
Sun radius	$692,000$ km	.. 6.9×10^{18} "
Moon from earth	$384,000$ km	.. 3.8×10^{18} "

Jupiter radius	$72,000$ km	.. 7.2×10^7 "
Earth equator	$40,070$ km	.. 4×10^7 "
Earth radius	$6,377$ km	.. 6.4×10^6 "
N.Y. to San Francisco (highway)	$5,230$ km	.. 5.2×10^4 "
" " (air-line)	$4,451$ km	.. 4.4×10^4 "
Moon radius	$1,740$ km	.. 1.7×10^4 "
1 kilometer = 1000 m = $1,000,000$ mm	..	10^4 "
Denver above sea-level	$1,638$ m	.. 1.6×10^3 "
Steamer Europa, length	285 m	.. 2.8×10^2 "
Lowest sound wave	16 m	.. 1.6×10^1 "
Man, average height	172 cm	.. 1.72 "
1 meter = 1000 mm = $1,000,000$ μ = 10^{-3} km = 1		
Highest sound wave	17 mm	.. 1.7×10^{-2} "
1 millimeter		
" 1000μ = $1,000,000$ $\mu\mu$	= 10^{-8} km	.. 10^{-8} "
Smallest visible particle	50μ	.. 5×10^{-6} "
Cells of Drosophila	7.25μ	.. 2.5×10^{-5} "
Nucleus of Drosophila	5.15μ	.. 1.5×10^{-4} "
Chromosomes of Drosophila	$0.2-3 \mu$	.. 3×10^{-6} "
Coccus bacteria	2μ	.. 2×10^{-6} "
1 micron (μ) = 1000 m μ = $1,000,000$ $\mu\mu$	..	10^{-9} "
Red blood corpuscle	$800 \mu\mu$	.. 8×10^{-7} "
Red light wave	$770 \mu\mu$	.. 7.7×10^{-7} "
Smallest microscopic particle	$300 \mu\mu$	.. 3×10^{-7} "
Average path of hydrogen	$170 \mu\mu$	.. 1.7×10^{-7} "
Large colloidal particle	$100 \mu\mu$	.. 1×10^{-7} "
Shortest ultra-violet wave	$13 \mu\mu$	.. 1.3×10^{-8} "
Thickness of oilfilm	$5 \mu\mu$	.. 5×10^{-9} "
Ultramicroscopic particle	$4 \mu\mu$	.. 4×10^{-9} "
Molecules	0.2 to $5 \mu\mu$	.. 5×10^{-9} "
Gas molecule distance	$1 \mu\mu$	.. 1×10^{-9} "
1 millimicron ($m\mu$)		
" 1000 micromicrons ($\mu\mu$)	=	10^{-9} "
Sulfur atoms, distance	$900 \mu\mu$	.. 9×10^{-10} "
Atoms	$100-600 \mu\mu$	.. 6×10^{-10} "
Silver atoms, distance	$400 \mu\mu$	.. 4×10^{-10} "
Soft x-ray wave	$136 \mu\mu$	.. 1.4×10^{-10} "
1 Angström = $100 \mu\mu$		
" 1000 millängström ($m\AA$)	=	10^{-10} "
Electron orbit in hydrogen	$53 \mu\mu$	.. 5.3×10^{-11} "
Hard x-ray wave	$19 \mu\mu$	.. 1.9×10^{-11} "
1 micromicron ($\mu\mu$)		
" 10 x-units (λ) or m μ	=	10^{-12} "
Shortest gamma ray	$2 \mu\mu$	.. 2×10^{-12} "
Longest cosmic ray	$0.6 \mu\mu$	.. 6×10^{-12} "
Shortest cosmic ray	$0.04 \mu\mu$	.. 4×10^{-14} "
Electron diameter	$0.038 \mu\mu$	.. 3.8×10^{-18} "
Nucleus of gold atom	$0.0004 \mu\mu$	.. 4×10^{-17} "
Nucleus of hydrogen atom	$0.00002 \mu\mu$	.. 2×10^{-18} "

2. THE DIMENSION OF MASS

Perhaps the largest figure calculated by man is the mass of the Einstein universe, namely, an eight with seventy-eight ciphers behind it. Compared with this amount, the galaxy to which our solar system belongs is insignificant, for it has but fifty-five zeros, that is a heptillion times lighter in weight—let the galaxy be an apple, the universe will be the earth. Within this galaxy it is most interesting to find that all stars,

whether giants or dwarfs, have approximately the same mass (although vastly different in size), for their mass varies between 32 and 26 ciphers. The sun, one third million times heavier than the earth, belongs to the smaller stars. The largest planet is 317 times heavier than the earth and our satellite has but one eighty-first part of the earth's mass. Coming down to earth we find the estimated mass of the hydrosphere, that is the oceans, lakes, rivers, snows and ice to be but one six hundredths part of the earth and not quite five hundred times greater than the mass of the atmosphere. Yet the mass of the atmosphere is considerable—and over five times the average mass of an asteroid. The annual fall of meteorites nearly reaches the tonnage of the steamer, *Bremen*, and between this magnitude and the weight of man himself we may enlarge our table *ad libitum*.

Turning to those small quantities which we call "traces" we note with interest that the effective dose of vitamin A is three thousand millionth of a gram, approximately the same amount of magnesium can just be detected by chemical means. Much smaller traces of sodium are detected by the flame test, still smaller amounts of mercaptane are perceptible by its odor. Most sensitive for detecting traces, however, is the spectroscope, and this in turn is apparently surpassed by the new magneto-optic method of Allison and others. The masses of colloidal particles and proteins molecules are overlapping. The largest molecule which has been synthesized is maltosazone, which is about twice as heavy as the artificial peptide or protein. The oilfilm must be assumed to be of single molecular thickness, for a minute square of it comes close to the weight of a stearine molecule. Sugar molecules are small in comparison to proteins and fats, yet still heavier than the heaviest atom, uranium. The lightest atom,

hydrogen, corresponds to the weight of a nucleus or proton and as such is still eighteen hundred times heavier than the electron. At present the electron is the

TABLE 2
MAGNITUDE IN MASS

Einstein universe	8×10^{78} gm
Galaxy (Milky Way system).....	2.3×10^{55} "
Large stars	1×10^{50} "
Sun $331,950 \times$ earth.....	1.99×10^{33} "
Small star	1×10^{32} "
Jupiter $317 \times$ earth.....	1.9×10^{29} "
Earth 1.0 earth.....	5.99×10^{24} "
Mercury $1/25 \times$ earth.....	2.5×10^{23} "
Moon $1/81,56 \times$ earth.....	7.5×10^{24} "
Hydrosphere $1,335,000,000,000$ Mill.tons	1.3×10^{24} "
Atmosphere $5,033,000,000$ "	5.6×10^{21} "
Average asteroid $1,000,000,000$ "	1×10^{21} "
Steamship <i>Bremen</i> $51,656$ tons	5.2×10^{10} "
Meteorite, annual fall 40,000 "	4×10^{10} "
1 ton = 1000 kg (2205 pounds)....	1×10^6 "
Man, average weight 76 kg (166 pds)...	7.5×10^4 "
1 kilogram (kg) = 1000 gm (2.2 pds)	1×10^3 "
1 gram (gm) = 1000 mg (15.4 grs)	1 "
1 milligram (mg) = 1000 μ g	1×10^{-3} "
1 microgram (μ g) = 1000 γ	1×10^{-6} "
1 gamma (γ) = $0.000,000,001$ gm	1×10^{-9} "
Vitamin A, effective dose 3 γ ..	3×10^{-9} "
Magnesium by chemical test 2 γ ..	2×10^{-9} "
Microbalance sensitivity 0.4 γ ..	4×10^{-10} "
Sodium by flame test 0.07 γ ..	7×10^{-11} "
Mercaptan by odor 0.002 γ ..	2×10^{-12} "
Gold particle (0.000,01 cc cube)..	2×10^{-14} "
Colloid particle (0.000,000,5 cc cube)..	2×10^{-15} "
Protein molecule $100,000 \times$ H..	1×10^{-15} "
Maltosazone molecule $4,021 \times$ H..	6.7×10^{-21} "
Octodecapeptide molecule $2,112 \times$ H..	3.5×10^{-21} "
Oilfilm (0.000,000,2 cc square).....	2×10^{-21} "
Tristearine molecule $890 \times$ H..	1.5×10^{-22} "
Cane-sugar molecule $342 \times$ H..	5.7×10^{-22} "
Uranium atom $238 \times$ H..	4×10^{-22} "
Water molecule $18 \times$ H..	3×10^{-22} "
Hydrogen atom $1 \times$ H..	1.663×10^{-24} "
Electron $7/1845$ of H..	0.01×10^{-28} "

lightest thing. Protons small and heavy, electrons larger and lighter, may compare with each other like a small and heavy star, as Van Maanen's star or the companion to Sirius, and a very large and light star, as Betelgeuze or Antares.

3. THE DIMENSION OF TIME

It is calculated that solar energy comes from a transformation of mass into radiations, that the matter of the sun dwindles in proportion to the light

emitted, hence the sun will slowly diminish its mass. To shrink to half its size we shall have to wait 500 billion years or twenty times longer than for the same process to happen to thorium. Thorium, the longest living member of the radioactive elements, has an average life four times as long as uranium. The Sitter universe, that is the system of galaxies, is assumed to double its size every fourteen thousand million years; this is a comparatively short epoch for such a gigantic undertaking, and this figure will probably be revised in future. The geologic age of the earth approaches close to the time required for doubling the universe, and about one half of this time was spent by the earth in the Proterozoic era and a quarter of it in the Paleozoic era. During the Proterozoic era the sun has traveled four times around the hub of the Milky Way, the solar year being two hundred million years. Since the birth of Christ the newly discovered planet, Pluto, has made over six trips around the sun. Curiously enough, the steam engine, revolutionizing industry, and oxygen, founding modern chemistry, were invented and discovered at about the same time. The foundation of organic chemistry dates but three generations back to the synthesis of urea, and the cornerstone of modern physics is but one generation old with the discovery of radium and x-rays.

Turning to short time intervals we find that the instant which a single image of the moving pictures remains on the screen is but a small fraction of a second but much longer than the fast photographic shutter. The fastest photographic device seems to be the chronotine, an instrument with many photographic lenses and continuous film movement used to take pictures of fast moving machineries which can be speeded up to a series of 10,000 pictures per second. Short-lived are the frequencies of

TABLE 3
MAGNITUDES IN TIME

Sun diminishing one half its mass.....	1.5×10^{30} sec
Thorium, average life 25,000,000,000 yrs	7.7×10^{11} "
Uranium, average life 6,300,000,000 "	1.9×10^{11} "
Earth age (He in rocks) 2,000,000,000 "	6×10^{10} "
Universe, doubling in size 1,400,000,000 "	4.3×10^8 "
Earth, Proterozoic era 850,000,000 "	2.6×10^8 "
Earth, Paleozoic era 420,000,000 "	1.3×10^8 "
Sun period in Milky Way 200,000,000 "	6.2×10^8 "
Earth, Quaternary period 1,500,000 "	4.6×10^8 "
Ioniun, average life 120,000 "	5×10^8 "
Dawn of history 6,000 "	1.9×10^8 "
Birth of Christ 1,932 "	6×10^7 "
Pluto period around sun 282 "	8.7×10^7 "
Neptune period around sun 164.7 "	5×10^8 "
Steam engine invented 157 "	4.9×10^8 "
Oxygen discovered 157 "	4.9×10^8 "
Urea synthesized 102 "	3.1×10^8 "
Man, average life 42 "	1.8×10^8 "
Radium and x-ray discovered 85 "	1×10^8 "
1 year = 31,536,000 sec	3.1×10^8 "
Earth period around sun 365.2 days.....	3.1×10^8 "
Mercury period around sun 87.98 "	7.6×10^8 "
Uranium X ¹ , average life 35.4 "	3×10^8 "
Moon period around earth 27.8 "	2.3×10^8 "
Sun rotation 24.6 "	2×10^8 "
Radium E, average life 7 "	6×10^8 "
1 day = 86,400 sec	8.6×10^8 "
Earth rotation, 23h. 56m. 4 sec	8.6×10^8 "
1 hour = 3,600 sec	3.6×10^8 "
Radium A, average life, 4.5 sec	270 "
1 minute = 60 seconds = 60,000 sigmas	60 "
1 second = 1,000 sigmas (σ)	1 "
Motion-picture image on screen 64 σ	6.4×10^{-2} "
Engine wheel period (1,500 r.p.m.) 40 σ	4×10^{-2} "
Alternating current cycle 10 σ	1×10^{-2} "
Sound vibration (C ₃) 4 σ	4×10^{-3} "
Sound vibration (C ₄) 2 σ	2×10^{-3} "
Photographic shutter, fastest 1 σ	1×10^{-3} "
1 sigma (σ) = 1,000 millisigma (m σ)	1×10^{-6} "
Chromatine image 100 m σ	1×10^{-4} "
Oscillograph 1 m σ	1×10^{-4} "
Radium C', average life 1 m σ	1×10^{-4} "
1 millisigma (m σ)	1×10^{-6} "
= 1,000 microsigma ($\mu\sigma$)	1×10^{-9} "
High frequency cycle 100 $\mu\sigma$	1×10^{-7} "
Radio oscillation 80 $\mu\sigma$	8×10^{-8} "
Lingering period of excited atom 1 $\mu\sigma$	1×10^{-9} "
Thorium C', average life 1 $\mu\sigma$	1×10^{-9} "
1 microsigma ($\mu\sigma$) = 0.000,000,001 second.	1×10^{-24} "
Yellow light oscillation	5×10^{-24} "
Cosmic ray oscillation	1×10^{-25} "

the waves of sound and light. They vary in proportion to the wave-length down to the shortest recorded time for a cosmic ray oscillation. Before reaching this extreme we find the nearly instantaneous birth and death of a radium C' atom or a thorium C' atom, likewise the

short lingering period of an excited atom, that is, the time required for an excited atom to stay excited.

4. THE DIMENSIONS OF VELOCITY

The fastest thing in the universe, and also the most constant one, is light. No matter how long it has traveled or how far it has gone, it speeds on with equal velocity and thereby serves as an astronomical yardstick, the light year. Its fundamental nature makes it also of importance in the subatomic world, where c , the velocity of light, enters into many fundamental equations. Electrons are a close second for honors as racers, for with sufficiently high voltage they can be made to speed on with light. The alpha particles emitted from the radioactive elements have an initial velocity about a hundred times less than light, but they soon tire and stop. Curiously enough, this is approximately the same velocity with which the Sitter universe is expanding or the farthest spiral nebula is receding. Compared with such speeds, the motions within the Milky Way are sluggish, for the sun moves along at the rate of 200 miles per second or seven times as fast as the fastest planet and about seventy times as fast as the slowest planet, Pluto. Neptune's speed around the sun is about equal to the speed of sound in iron and this is but twice as fast as the motion of hydrogen molecules in a container at zero Centigrade. Yet the hydrogen molecules move twice as fast as a rifle bullet leaving its muzzle. The rotation of the earth at the equator, with reference to the sun, is about the same swiftness as that with which oxygen molecules travel at the freezing point of water. The moon travels very leisurely and slowest of all heavenly bodies, with 534 feet per second; this is about one half as slow as sound dashes through the air and nearly twice as fast as the fastest racing car running 254 miles per

hour. A nerve impulse compares favorably with the speed of modern railroads and automobiles, while a paper-making machine is conservative and turns out a roll of paper at the rate of fifteen miles an hour.

TABLE 4
MAGNITUDES IN VELOCITY

Light	186,000	$\left\{ \begin{array}{l} \text{mi.} \\ \text{per} \\ \text{sec.} \end{array} \right\}$	2.99×10^{10} cm/sec.	
Electrons in cathode rays	.....	10^6 to 10^{14}	"	
Alpha-particles, initial velocity	20,000	$\left\{ \begin{array}{l} \text{mi.} \\ \text{per} \\ \text{sec.} \end{array} \right\}$	3.2×10^8	"
Farthest spiral nebula (recession)	12,300	" ...	2×10^8	"
Sun, around hub of Milky Way	200	" ...	3×10^7	"
Mercury around sun	29.7	" ...	4.78×10^4	"
Earth around sun	18.33	" ...	2.05×10^4	"
Neptune around sun	3.37	" ...	5.43×10^3	"
Sound in iron	3.1	" ...	5×10^3	"
Hydrogen molecules at 0° C.	1.11	" ...	1.8×10^3	"
Sound in water	0.9	" ...	1.46×10^3	"
Rifle bullet in air	1,070	$\left\{ \begin{array}{l} \text{ft.} \\ \text{per} \\ \text{sec.} \end{array} \right\}$	6×10^4	"
Nitrogen molecules at 0° C.	1,630	" ...	4.97×10^4	"
Earth rotation at equator	1,525	" ...	4.65×10^4	"
Oxygen molecules at 0° C.	1,525	" ...	4.65×10^4	"
Sound in air	1,089	" ...	3.32×10^4	"
Moon around earth	534	" ...	1.63×10^4	"
Speed car on racing beach	370	" ...	1.14×10^4	"
Wind at 100 miles p.hr.	150	" ...	4.57×10^4	"
Nerve impulse	128	" ...	3.9×10^3	"
60 miles per hour	88	" ...	2.86×10^3	"
20 miles per hour	29.2	" ...	9×10^2	"
Paper-making machine	16.6	" ...	5×10^2	"
1 centimeter per second.....			1	"
Crystal growth (plastic acid)	14.3	$\left\{ \begin{array}{l} \text{mm} \\ \text{per} \\ \text{sec.} \end{array} \right\}$	1.43	"
Gas diffusion (H into O)	6.9	" ...	0.09	"
Fastest plant growth	0.03	" ...	3×10^{-3}	"
Crystal growth (o-phosphoric acid)	0.018	" ...	1.8×10^{-3}	"
Growth of beard	0.0001	$\left\{ \begin{array}{l} \text{mm} \\ \text{per} \\ \text{sec.} \end{array} \right\}$	1×10^{-6}	"
Diffusion of gold into lead	0.002	$\left\{ \begin{array}{l} \text{mm} \\ \text{per} \\ \text{day} \end{array} \right\}$	4.6×10^{-9}	"

Turning to slow motions we find that picric acid is among the fastest growing crystals, it grows about one eighth of an inch in two seconds; about half as fast is the diffusion of hydrogen into oxygen. The fastest growing water plant is three hundred times as swift as the growing beard of a freshly shaved man. Among the slowest of the slow is the speed with which gold atoms diffuse into lead. No attempt has been made to evaluate the slowest motion of all, the displacement of stars in the line of sight, which naturally is only apparent and represents not the true notion. In astronomy we find the fastest and the slowest motions.

5. THE DIMENSION OF TEMPERATURE

Compared with other magnitudes, the range from one extreme to the other is very small in theoretical and practical temperature. The relations seem simpler and can be grasped more readily: thus from the hottest climate in Tripoli or Death Valley to the coldest climate in Alaska or Northern Siberia, there is but a difference of 110° C.; while between the greatest heat artificially produced and the greatest cold achieved experimentally, there is about $5,700^{\circ}$ C. difference; but theoretically the temperature in the stellar interior reaches forty million degrees, which still leaves the entire range of temperatures within seven ciphers. From the hottest stellar interior there is a gradual drop in temperature as we reach the stellar surface; this drop is so large that even in the hottest stars, Class B type, the surface temperature is but one two-thousandth, or $23,000^{\circ}$ C., while the coldest visible stars, Class M type, have $3,000^{\circ}$ C. at their surface and thus come within the range of temperatures produced artificially upon our earth. The sun surface is about three times hotter than the oxy-hydrogen blowpipe; this temperature can be closely approached on earth in the focus of a system of nineteen

lenses, a sun or solar furnace. The atomic hydrogen torch is not very far behind and is followed closely by the marvelous induction furnace which heats conductors as high as they can stand, usually up to their melting point. Besides graphite, tungsten has the highest melting point of any element. Of organic compounds the highest melting

TABLE 5
MAGNITUDE OF TEMPERATURE

Stellar interior	$72,000,000^{\circ}$ F. . .	$40,000,000^{\circ}$ C.
Stellar surface (B star)	$41,000^{\circ}$ F. . .	$23,000^{\circ}$ C.
Solar surface (G star)	$10,800^{\circ}$ F. . .	$6,000^{\circ}$ C.
Sun furnace (focus of 19 lenses)	$10,000^{\circ}$ F. . .	$5,500^{\circ}$ C.
Atomic hydrogen torch	$7,600^{\circ}$ F. . .	$4,200^{\circ}$ C.
Induction furnace (conductors)	$7,200^{\circ}$ F. . .	$4,000^{\circ}$ C.
Electric arc in vacuum	$5,400^{\circ}$ F. . .	$3,000^{\circ}$ C.
Stellar surface (M star)	$5,400^{\circ}$ F. . .	$3,000^{\circ}$ C.
Tungsten, melting point	$5,350^{\circ}$ F. . .	$2,970^{\circ}$ C.
Oxy-hydrogen torch	$3,600^{\circ}$ F. . .	$2,000^{\circ}$ C.
Gas burner	$3,000^{\circ}$ F. . .	$1,700^{\circ}$ C.
Rubrene, melting point	932° F. . .	501° C.
Water, boiling point	212° F. . .	100° C.
Hottest climate (Tripoli) (Death Valley)	136.4° F. . .	58° C.
Man, body temperature	98.6° F. . .	37° C.
Ocean water (La Jolla)	78.4° F. . .	25.7° C.
Water, freezing point	32° F. . .	0° C.
Mercury, freezing point	-37.8° F. . .	-38.8° C.
Coldest climate (Alaska) (Northern Siberia)	-82° F. . .	-63.3° C.
Liquid air	-319° F. . .	-195° C.
Interstellar space	-454° F. . .	-270° C.
Hydrogen freezes	-458° F. . .	-272.2° C.
Lowest experimental temperature	(0.75° A.) . . .	-272.38° C.
Absolute zero (0° A.) . . .		-273.13° C.
	(1° F. - 0.5556° C. and 1° C. - 1.8° F.)	

point has the hydrocarbon rubrene. Within the narrow range of about five hundred degrees are the melting and boiling points of all organic compounds. Climates hotter or colder may have been reported, but either inaccurate thermometers or improper methods have been used and at present the most reliable figures are 136.4° F. for the hottest and -87° F. for the coldest climatic temperature. This is far above the temperature of liquid air or liquid hydrogen. Coldness is harder to produce than

hotness. It takes more energy to cool than to warm, and scientific progress is difficult, for each tenth of a degree is an achievement as we approach absolute zero. Interstellar space is about three degrees above absolute zero and experimental methods have reached temperatures within three fourths of a degree of absolute zero.

CONCLUSIONS

In making this short inventory of magnitudes but a few physical properties have been selected. It is found that the range of magnitudes varies, it is greatest in mass and smallest in temperature.

RANGE OF MAGNITUDES

(1) Length	... . . . .	10^{34} m
(2) Mass	... . . . .	10^{58} gm
(3) Time	... . . . .	10^{41} sec.
(4) Velocity	—	10^{20} cm/sec.
(5) Temperature	.. . . .	10^7 °C.

Naturally many other properties, such as calories, pressure, volume, density, electric charge, magnetic moment, etc., could have been selected in this inquiry into the largest and smallest and would have offered a similar interesting excursion to the frontiers of science—interesting to those who can realize the human effort necessary for discovering these figures.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

FLYING THROUGH THE ANCIENT NEAR EAST

By CHARLES BREASTED

ORIENTAL INSTITUTE, UNIVERSITY OF CHICAGO

THOSE of you who have traveled in the near Orient know that to-day between England and India and South Africa, between Holland and Java, between France and Cochinchina, and between Germany and Russia and Persia there are in operation regular passenger and mail air services. Amateur solo flyers over these routes may break into the headlines for apparently remarkable exploits. But quietly, week after week, through blazing desert heat or across snow-capped ranges, through dust storms sometimes sixteen thousand feet deep, and over tropic seas, the pilots of these various airlines carry on over their long air trails. Only when you have crawled across these dreary stretches by caravan or motor car or even by ship can you fully appreciate the vast amount of time and effort saved by air travel.

Before sharing with you a flight made through the Near East for the especial purpose of securing a motion-picture record of our field work, whence I have just returned, let me explain briefly the nature of the Oriental Institute of the University of Chicago. With twelve field expeditions scattered through Egypt, Palestine, Syria, Turkey, Iraq and Persia, it is to-day the largest archeological research organization in the world. It was created in 1919 by Dr. James H. Breasted, its director, with funds appropriated by Mr. John D. Rockefeller, Jr., and its subsequent expansion has been due both to him and to two of the Rockefeller boards, as well as to various individual supporters. The

institute's beautiful new headquarters building on the quadrangles of the University of Chicago constitutes the first laboratory ever set up for the study of the rise of man from remotest savagery to the conquest of civilization. The main floor of this headquarters is given over to a group of exhibition halls, where in less than an hour you may gain a bird's-eye view of the whole career of man in terms of man's own handiwork, both practical and artistic.

The Near East—where civilization first arose—is to-day literally a great warehouse of buried ancient cities and towns filled with the paraphernalia of man's daily existence thousands of years ago—equipment long since “written off” by the inexorable wear and tear of history. These ancient cities are now silent mounds, representing layer upon layer of different periods and civilizations. Armies conquered a place, burned and ruined it, and presently either the victors or what remained of the original inhabitants would level off the ruins and construct upon them a new city. Or merely the disintegration wrought by time and weather, as any present-day oriental town will bear witness, would cause buildings to tumble in, necessitating the creation of new ones upon the old. Thus, by what we call the process of “urban stratification,” there grew up city mounds, great “layer cakes” of different civilizations and periods which the Oriental Institute and other scientific archeological organizations are systematically excavating. From the ma-

terials thus unearthed we are able to reconstruct not only the buildings and furnishings of a given period, but even the life which once pulsed through the ancient streets—how kings ruled, armies fought, ordinary folk tilled their fields, bartered and traded, married, begat families and at length died and were buried. Along a far-flung front of over thirty-five hundred miles, from Upper Egypt on the south, Turkey on the north to Persia on the east, the expeditions of the Oriental Institute are meticulously, painstakingly gathering, excavating, recording, exploring; and out of this new, synthetic attack upon the story of mankind, which enlists the assistance of geologists, paleontologists, ethnologists, anthropologists, botanists, medical men, chemists, archeologists, philologists and historians, it is hoped there will grow the authoritative, interpretative history of civilization.

Because the field work of this widespread organization had never been recorded in motion pictures, your speaker persuaded Dr. Breasted, his chief, to lend his services toward the production of a talking picture to be called "The New Past," of which Part I should contain a synopsis of the rise and development of civilization, and Part II a vivid survey of the Oriental Institute's leading field expeditions in the Near East. Part I was completed at Chicago last February with notable success; but the completion of Part II was a much more ambitious undertaking and became the major business of your speaker's annual visit to our field projects.

In every department of its work the Oriental Institute has always tried to avail itself of the latest developments of science, from sound pictures and aviation to the delicate technique of modern excavation and recording. Finding upon my arrival in Cairo last March that quite by chance the well-known English pilot, Captain Gordon P. Olley,

chief charter pilot of the Imperial Airways, Limited, was in Cairo with an Avro Ten—a trimotored Fokker type 10-passenger monoplane—I welcomed the opportunity of chartering this machine with an additional crew of two, consisting of radio operator and assistant pilot, for an air visit to our widely scattered expeditions. The renown of Captain Olley among his colleagues arises from a brilliant war record and subsequent flying now totaling well over ten thousand hours—more than eighteen months of his life—in the air! His skill and trustworthiness is attested by his having so frequently carried across Europe the Prince of Wales, the King of the Belgians and other notables whose lives belong to their people.

Accompanied by Mr. Reed Haythorne, our cameraman especially dispatched from America, we took off at dawn on March 23rd from Heliopolis airdrome outside Cairo and headed northeast for Biblical Gaza in Palestine, where we refuelled before continuing on across the Dead Sea, Transjordania and the nearly six hundred miles of desert beyond which lies Baghdad. In the middle of this desert lies a tiny Beau-Geste-like fortress guarding the ancient Rutbah Wells—a place no larger than a pinpoint on the map, yet by means of Marconi's remarkable new direction finder, a haven for all the air services. Behind its barbed wire entanglements and machine gun emplacement you may eat an excellent meal while your plane is being refuelled. Every drop of gasoline and morsel of food has been hauled across the desert from Damascus or Baghdad by motor convoy.

From Rutbah we flew on to Baghdad through a fiendish dust storm in which visibility was nil and progress was possible only by constantly establishing our position through radio. Captain Olley, who had never before flown this route, literally bisected the Baghdad airdrome,

and brought us safely down. After a sleepless, choking night, the dust settled as suddenly as it arose, and we were able to record in "movies" the work of our Iraq Expedition, stationed about 50 miles out in the barren plain northeast of Baghdad, where we are excavating two large ancient Babylonian cities, the latest "layers" of which date from 2500 B. C., or some 4,500 years ago.

Thence we pushed on to Basra, the great port of Iraq on the Persian Gulf, and on to Bushire, our airport of entry into Persia. The dust had risen again and we felt our way along the Persian coast in a twilight through which, after Bushire, we had to climb to 12,000 feet before we found the clear sunlight. The silver-tan peaks of three great mountain ranges stood out in the late sun, like islands in a vague sea of gray-brown dust; and here and there the islands were covered with snow. Sailing along in the even, cold upper air we came at length to Shiraz, which lies in a plain over five thousand feet above sea-level, and thence by car continued to Persepolis, the most magnificent site of the ancient world, with the single exception of the Acropolis at Athens.

Persepolis, the capital of the Persian Empire built by Darius the Great about 500 B. C. and destroyed by Alexander the Great in 331 B. C., stands at the base of a black mountain on a great terrace built of gigantic blocks of stones taller than a man, and surveys a vast plain encircled by mountains. Here ruled the emperors of ancient Persia—and here to-day the Oriental Institute is excavating and restoring this place of transient grandeur. Our expedition headquarters is the reconstructed harem of Darius! Needless to say, our cinema record of Persepolis—the first one ever made on standard size film—is of remarkable interest.

From Persepolis we drove back to Shiraz (a distance of some 40 miles)

and once more enplaned for Bushire and Baghdad, where we were again delayed by a dust storm—the one in which Colonel Regnier, president of the League of Nations Frontiers Commission, crashed with pilot and companion as they were en route from Damascus to Baghdad to consider the realignment of the frontiers of Kurdistan, where at the moment the mountaineers are in a state of war. As we took off from Baghdad early on the morning of March 30, we watched the funeral cortege bringing the bodies to two waiting Royal Air Force bombers which flew them to Damascus.

After recording the institute's work at Khorsabad, some eighteen miles northeast from Mosul, where we are excavating the palace and city of King Sargon II, once ruler of Assyria, from whose palace the Institute secured the great winged stone bull now installed in its exhibition halls here at the Chicago headquarters, we continued on, southward across the desert, *via* Rutbah to the shores of the Lake of Galilee, whence by car we achieved our expedition excavating the Mound of Megiddo, which guards the pass leading through the Carmel Range of hills. Every army of ancient times, marching from Palestine to Egypt or the reverse, had to use this pass, and even in the late war, Lord Allenby sent through it in a single night his 20,000 cavalry. It was natural that in very early times so strategic a point should be occupied by a town which gradually grew to large proportions. The Institute is peeling off stratum after stratum of different occupations, and at present has laid bare the city of the time of Solomon (about 950 B. C.), where you may walk through the stables once occupied by his blooded horses which he traded with neighboring countries. Here we made a fascinating picture record, including that of a newly discovered tomb deep in the native rock.

From Megiddo we returned to the Lake of Galilee and took off again, circling over Nazareth and Haifa, and above Megiddo, photographing as we went, and southward to Jerusalem, and at length back over the Suez Can'l to Cairo, where we added to our ground record of Luxor and Memphis air views of the great Pyramids, the step Pyramid and the ancient cemetery of Memphis, before coming down once more at Heliopolis airdrome.

On a magic carpet, albeit to the roar of three motors, we had circled the major portion of the ancient Near East, had secured some twelve thousand feet of unique motion-picture record, and had in the face of every sort of obstacle, returned to our starting point on absolutely scheduled time. I can conceive of the day—it may even be upon us now—when a far-flung archeological organiza-

tion will find its own aircraft indispensable to the maximum efficiency of its field work.

In conclusion, for those of you who are asking what disposition we expect to make of this motion-picture record, let me say that we shall select from it the material necessary for completing "The New Past," to the accompaniment of Dr. Breasted's voice describing what you see. We shall also make from it at least two other pictures, both in sound. "The New Past" should be ready for release by March, 1933, and possibly also most of the shorter pictures. While "The New Past" in its original version is being prepared primarily for audiences in educational institutions—colleges, schools and other groups—it is not unlikely that a more popular version will be prepared for wider showing.

ECHOES GIVE OCEAN DEPTHS¹

By Dr. HERBERT GROVE DORSEY

PRINCIPAL ELECTRICAL ENGINEER, U. S. COAST AND GEODETIC SURVEY

ECHOES, which are made by sounds reflected back to you, are heard on all sides and by everybody; you are so used to hearing them that they are seldom noticed unless the echo is heard at a considerable time interval after the sound is produced. In a room with bare walls we hear the echoes so quickly that the result is called reverberation and considerable money is spent preventing reverberation in a broadcasting studio. Being so common, you would scarcely believe that echoes are useful and can save time and money as well as promote safety at sea.

Safety at sea was on everybody's lips after the tragic disaster of the *Titanic*, twenty years ago. How could the sea be

made safer; how could we know when icebergs might be near enough to cause danger? Many minds were turned towards a solution of this problem and one mind, at least, thought of the possibility of receiving a submarine echo from an iceberg by a sound produced in water. The experiment was actually tried by Professor Reginald A. Fessenden, and whether he received echoes from the iceberg seems to be omitted from the record. But he did succeed in getting echoes from the bottom of the ocean, which was perhaps more important, for the sea always has a bottom, while you can't find icebergs on every little summer's outing at sea.

While you get echoes so easily in air you will be surprised to know that you can hear them more easily in water, for

¹ Publication approved by the Director of the Coast and Geodetic Survey of the U. S. Department of Commerce.

sound travels better in water than in air, travels faster and farther. It passes through water so much faster, about four and one half times, that it is not easy to measure shallow ocean depths by the echo method because the time interval is so short. In water, sound travels about 4,800 feet per second and since a fathom is six feet the sound will go down and back through a depth of 400 fathoms in one second, or through a depth of one fathom in one four hundredth of a second, which is only two and one half thousandths of a second. We think of a stop watch measuring to a fifth of a second as being very fast. It used to be the last word in timing horse races, but in this day and age, when we hear so much about split seconds, it is entirely too long even for races!

Measuring ocean depths is probably as old as the art of sailing ships, for Herodotus some four hundred years B. C. mentions putting grease on the bottom of the sinker to bring up a sample of the bottom. No practical improvements were made for twenty-three centuries, until Lord Kelvin utilized the idea of pressure tubes, which was still further improved in accuracy by Commander G. T. Rude, of the Coast and Geodetic Survey. While Fessenden's method would work in deep water, it was cumbersome, requiring a skilled observer to use headphones and listen intently to distinguish the difference between echoes and water noises, and it was absolutely impossible to measure shallow depths with it. Ship captains were not interested in it and nothing was done commercially. Although several attempts were made to produce something better, Fessenden's model lay practically dormant until 1922.

At that time the Submarine Signal Company put two of its engineers on the problem, R. L. Williams and myself. Williams was a mechanical engineer, unfamiliar with radio, while I had just completed experiments on the radio loud

speaker, now so extensively used. Naturally, we attacked the problem along different lines, he holding to mechanical devices while I tried to tune everything and amplify the weak echoes. This desire to amplify was ridiculed because it was thought impracticable to attempt to use amplifying tubes on a ship unless under the constant supervision of the wireless operator. Of course amplification helped and proved to be the only way to success. On an experimental trip on the ship *Calamares*, the captain asked me if I could measure shallow depths and said, "When you can measure six to ten fathoms, you will be doing something!" It was not long after that when I had a visual method worked out in the following manner.

In one part of the equipment, called the indicator, there is a small motor with a governor which, through a system of gears, rotates a black disc four times per second. Attached to the back side of the disc is a tiny neon tube, just a small edition of the same as is used in advertising signs, and when it is illuminated its red light shines through a slot in the disc, but it is lighted only now and then. In front of the disc is a sheet of glass on which is painted a circular scale marked in fathoms from zero to 100. Every time the neon tube passes the zero point of the scale, an electric current passes through a sounder bolted to the bottom of the ship and a sound is produced as a short whistle blast, two octaves above middle C, like this: (Illustrate by whistling the short blasts for two seconds). Only these sounds pass into the water; no wire is lowered, nothing is dropped, no connection with the bottom is made. The sounds themselves do the work by being reflected from the bottom of the ocean as echoes.

As the echoes return to the ship they are "heard" by a receiver of submarine sounds, or electric ear as it might be called, and an amplifier using thermionic tubes, similar to those by which you are

now hearing my voice, increases the loudness of the echoes so that the electrical energy will cause the tiny neon tube to make a single brilliant instantaneous red flash of light as the tube whirls around with the disc. This flash will shine through the glass, opposite some mark on the scale, six fathoms, for example, if that happens to be the depth of water through which the ship is passing. Four times a second the red light flashes at six fathoms, thus measuring a time interval of only fifteen thousandths of a second, and you read the depth as easily as you read time on a clock. Now, as the ship travels through deeper water, the red flashes will occur at later intervals, making the indications move along the scale to show increasing depths. In going from deep water to shallow, of course the red flashes will follow the scale backwards just as well as forwards. If the depth increases to more than a hundred fathoms a handle is turned shifting to a slower speed and another scale, so that, while the indications come less often, the depths can be measured to 3,000 fathoms or more, nearly $3\frac{1}{2}$ miles of water.

Since the instrument measures fathoms, I named it fathometer, and as such the fathometer is now used on hundreds of ships measuring fathoms whenever the captain wishes. In former days, he would have to slow up the ship, if the water were shallow, or stop if it were deep, while now he presses a button, the fathometer starts and after a few readings to assure himself that he has plenty of water he pushes another button. It is all finished in a few seconds, even though the depth be a thousand fathoms! By the method of lowering a wire to measure this depth, the ship must be stopped at least a half hour, while now it can proceed at full speed, twenty to thirty knots, and in any kind of weather, day or night. With the fathometer right in the pilot house, the skipper has no anxiety about the depth.

In the United States Coast and Geo-

detic Survey, we are using fathometers on thirteen ships to chart the ocean depths. Since we can run the ships at full speed, we can get many more soundings than formerly, not only doubling the speed of hydrographic surveying, but getting so many soundings that we can make charts better and faster at lower costs than by the former, slower methods. With a ship speed of ten knots and four soundings per second, the depth is obtained about every four feet, so that even slight changes in ridges and valleys are now found which might not have been noticed by old methods. Every so often our ships are stopped and very careful measurements made with a wire and lead sinker, and serial temperatures of the water are taken so as to get an accurate correction on the fathometer, to keep it calibrated as a precision instrument. A little grab bucket at the end of the wire brings up a sample of the bottom. The fathometer can not do that, but as one watches the red flashes he can get some idea of the bottom, for the echoes are less regular from a rocky bottom than from a smooth one.

Since greater details are given in our charts, navigators are finding them much more useful than just mere road maps of directions at sea. The bottom is seldom flat for any considerable area and, if a navigator is lost in a fog, he can keep his fathometer running a few minutes, mark the indications on a piece of thin paper and by moving this around over the chart, keeping it parallel with his course, he will find some line on which his soundings will agree with those of the chart, locating not only his position and direction of travel, but giving also his speed. So vivid are the fathometer indications when steaming over rapidly changing depths that it is almost like seeing the bottom rise and fall as do the hills and valleys by the road side as you ride along in an automobile. The configuration of the ocean bottom is not unlike that of our land surfaces; some-

times changing so rapidly that it almost resembles cliffs, palisades and canyons. I have measured slopes in the China Sea and in the Pacific near San Francisco, which have about the same average grade as the mountains near the coast, while the ocean bed to the east of north Florida, while having a gentle slope towards Spain, is as flat as the state of Florida itself.

What do you suppose the fish think think about all this whistling? Well, by

watching them, in clear water, when the fathometer is first started, they appear frightened and rush away from the sound; but after ten or fifteen seconds they get used to it and swim around the ship as usual. Dog fish might try to bark at it—who knows! Herodotus probably knew about echoes as well as about grease on the bottom of the sinker, but I would like to watch his reaction to a fathometer while sailing the Aegean Sea.

FEEDING THE GROWING POPULATION

By Dr. WILLIAM CROCKER

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IN 1798, Malthus, an English economist, wrote his famous essay on "The Principle of Population as it Affects the Future Improvement of Society." He stated that at all times population has tended to overrun subsistence and that, while subsistence increased in arithmetical progression, population increased in geometrical ratio. Consequently, there could be no permanent amelioration of the lot of the lower classes, for while redistribution of wealth might bring them plenty for a time, population would soon overtake subsistence and they would again be kept in check by starvation or vice, unless checked by self-restraint. Malthus put this theory forth in part to answer what he believed to be two erroneous theories of his day. Certain statesmen, like Pitt, held that the increase in population was an unqualified advantage and socialists were advocating redistribution of wealth.

I do not want to dispute Malthus' theory as a theory. If population were to continue to increase with a constant and high geometric ratio, some time in the future food would limit population. I do want to take exception to the Neo-Malthusians with their alarmists' ideas

of such a disaster being imminent. In spite of these alarmists' ideas, we have more food to-day per population than we ever had before. To-day it is not a question of how to raise enough food for our population, but what we shall do with the great excess we produce. Also, never before were there such great possibilities of future increases in food production. We literally have food to burn and will continue to have for some time yet, unless we curtail production, and for a long time yet, unless we curtail threatened increases in production. One and one third centuries after Malthus' pronouncement that population always tends to overrun subsistence, the dictum has been quite reversed, increase in food production has overtaken increase in population, and the possibilities of enormous future increases in food production are just beginning to be realized.

Why the present-day reversal in the Malthusian conception? It is largely due to three changes that have occurred since Malthus' time and that could not, at that time, be foreseen: (1) The fall in the ratio of population increase amongst more highly developed nations; (2) invention of farm machinery; and

(3) research in plant and animal sciences, or agriculture.

Because of lack of time and the great importance of the second and third points, the first point must be passed over with a few illustrations. At the present rate, the populations of Cuba and Porto Rico are doubling once in 25 years and that of the United States, with limited immigration but large foreign population, once in 45 or 50 years, while France is showing little increase in population. The great decline in birth rate in the large cities of Germany and the United States in 1931, as compared with 1930, shows how economic stress and not man's power to produce food is likely to reduce the ratio of increase of population in more highly developed countries. Desire of ease amongst the middle and upper classes of such nations has a similar effect.

Invention and development of effective farm machinery during the last 80 or 90 years has reduced greatly the amount of manual labor necessary for producing man's food, and the resulting ease in food production has led to a growing surplus. The United States and the British Isles have furnished most of the inventors in this field. Amongst these should be mentioned Cyrus Hall McCormick, inventor of the reaper, and John H. Appleby, inventor of the twine knotter that made the self-binder possible. With the grain sickle, it required five men one day to cut and bind one acre of wheat. With the cradle, two men would accomplish as much. With the reaper, one man could cut and bind two acres a day. With the binder ten acres was a day's work for one man, and finally with the combine one man could cut and thresh ten acres a day. From the sickle to the self-binder man has increased his efficiency in harvesting his breadstuffs fifty-fold. From the crooked stick to the modern

gang plows pulled by tractors similar advances have been made in breaking the soil. A like advance has been made in cultivation of crops from the hand hoe to the four-row cultivator drawn by a tractor at twice the speed of a horse cultivator.

These examples are typical of what invention of farm machinery has done in increasing man labor efficiency in food production. In 1870, 90 per cent. of the population of the United States was on farms; in 1929, 22.9 per cent. Farm machinery has released about two thirds of the population of the United States for factory production of necessities, such as clothing and furniture, and for the making of luxuries—bathrooms, electric refrigerators, automobiles, etc. Before the invention of farm machinery, man used nearly all his time to produce his food and other mere necessities, and shortage of food and even famine were common. Now his granaries are always overflowing.

In 1900, and for some years afterwards, nearly all power on the farm and for city drayage was horse power, with hay and grain as its source. With motorization of farm work and city drayage, petroleum displaced hay and grain as a source of power and released much food for direct use by man or for indirect use through dairy, egg and meat production. If the horse had all his old jobs back in the United States to-day, corn and hay would be scarce and high-priced. Malthus, of course, could not foresee this releaseal of food which was to occur more than a century after he wrote his essay. When man converts vegetable materials into animal food materials, such as milk, butter, eggs and meats, he incurs a great loss in nutritive value and energy. If the direful day prophesied by Malthus approaches, man can push back the day of starvation by turning more and more to a vegetable diet.

Let us turn to the effect of agricultural research on food production. Much of the time of agricultural scientists has been devoted to working out methods of controlling diseases and pests of man's food plants and animals partly due to the fact that ever-increasing exchanges of plants and animals have distributed these diseases and pests to all regions of the earth and partly due to the ravages of pests within their native haunts. The efforts of the scientists in this direction have enabled man merely to hold his own against the detrimental agents to food production. Let us consider a few examples.

Just prior to 1900 a leafhopper was introduced into Hawaii from the South Sea Islands that threatened to completely wipe out cane production in the Hawaiian Islands. Several years of study and work by entomologists led to the introduction from the native home of the leafhopper insect pests that completely control it. Some years ago a disease of cabbage—cabbage yellows—threatened to wipe out the cabbage industry. Dr. L. R. Jones, of Wisconsin, saw a 20-acre field in which only a few heads were perfect and without disease. He said, "These plants are probably resistant to yellows." He grew seeds from these, and through many years of selection and intensive study now has resistant forms that grow perfectly in diseased soil. Through extensive, careful experimentation the cause, manner of transmission and remedies for Texas fever of cattle and cholera of hogs have been worked out. These are four of many such conquests scientific workers have waged successfully against pests and diseases that have threatened man's food supply. The background of scientific information and principles established in control of diseases and pests insure that future threats to man's food supply will be handled with even greater facility. Scientific men have

not merely met and conquered pest and disease threats to man's food supply, but they have made marvelous advances in the knowledge of plant and animal nutrition and breeding that add greatly to food-producing possibilities.

In 1840, Liebig, the great German chemist, put forth his theory of soil fertility. This stimulated Sir John Lawes, of England, to organize the first and most renowned agricultural experiment station, the Rothamsted Station at Harpenden, England. This tested and corrected Liebig's theories and established many of the laws of soil fertility. Basic knowledge in nutrition of plants and soil fertility has accumulated rapidly up to the present day and established a firm basis for increased crop yield. Let us observe three discoveries on soil fertility and plant nutrition within the present century that have led to great increases in food production. In the northwestern United States it was discovered that the soil was deficient in sulphur. By adding sulphur compounds to the soil, alfalfa yields could be raised as much as five-fold. The discovery that pineapples grown in various soils of Hawaii were starving for iron and that the iron had to be fed through the leaves as an iron sulphate spray made possible the development of the large pineapple industry of Hawaii. Recently, non-productive peat soils of Holland and the United States have been found to be deficient in copper. By addition of copper the soils become highly productive vegetable lands. The great development of knowledge in animal nutrition, though it came later, is also important in increasing production of animal materials for human foods.

Breeding and selection has done much to increase food production by plants and animals. Dr. William Saunders and his son, Dr. Charles Saunders, by fifteen years of breeding and selection of wheat, produced Marquis wheat, the

present spring wheat of western Canada. This wheat has about six days' shorter growing season than the Red Fife, which it displaced. It thereby misses fall frosts, which results in an increase in yield of nearly 30 per cent. Java's cane-breeding work, stretching over a period of more than 20 years, has produced the new P.O.J. canes that, under identical cultivation methods, produce three times as much sugar per acre as any of the canes entering into the crosses. More than fifteen tons of sugar per acre per crop have been produced. With these new canes and with improved methods of cultivation now known, two small islands, Cuba and Java, besides growing much other food for their people, can produce with profit all the sugar the world can eat at two cents a pound at the mills.

The extensive and thorough research in plant and animal sciences has placed in man's hand tools for an enormous increase in food production. Still more important, it has uncovered many facts and established many principles as a basis for future discoveries that may lead to increases in food production not dreamed of to-day. Besides all this, it must be remembered that the tropics, with tremendous possibilities for growing food, have been largely untouched as a region for food production. In closing it may be said that for a long time to come man's problem will not be as Malthus thought, production of enough food for his subsistence, but rather how to readjust his distribution system so that the whole population of the earth can benefit by the great power man has to produce food and other commodities.

SEEING THINGS AT A DISTANCE

By Commander C. L. GARNER

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PERHAPS all of you have climbed to the top of some high mountain, or, if not, to the top of a tall building or monument, and from these high places have seen objects at distances much farther than you thought it possible to see. This would be particularly true if you were so fortunate as to have fair weather and a clear atmosphere at the same time. Many of us are denied the experience and pleasure of looking out into open spaces, such as afforded those sailing high seas—or viewing the open expanses of water from a seaside cottage, or of scaling some high mountain—more than about once each year or perhaps every blue moon. On such occasions it is probable that some of these questions came to your mind. How far is the horizon?—that ship?—that mountain peak?—town or monument? How high

must it be in order to be seen that far? And, finally, How far after all do our eyes reach on this earth of ours?

The man on reconnaissance for triangulation, and the triangulator himself, must be familiar with these facts and the importance they bear to their work in order to plan and extend arcs of triangulation about the country without serious interruption or undue expense. Triangulation is the means employed by all nations of the world for the extension of large scale surveys around their boundaries and across their interiors for the control or coordination of all classes of public and private surveying activities. One of the prerequisites in the selection of triangulation stations is that each station must see practically all other stations adjacent to it in order that the observer may later occupy these same

points with a theodolite and accurately measure the angular values between the stations around the horizon. This work extends into all sections of the country, and in mountainous regions it is natural that many of the stations should be on high peaks and that many long lines between these stations would occur. Moreover, in the early days it was essential that the work progress across country as rapidly as reasonable economy would allow, as otherwise our mapping program would have proceeded at a much slower rate than the snail's pace it now has.

In the United States the longest line over which instrumental observations have been made at both ends of the line is between Mt. Shasta and Mt. St. Helena in California, a distance of 192 miles. Another long line was between Mt. Ellen, Utah, and Uncompahgre Peak, Colorado, a distance of 183 miles. In both cases the observations were made on heliotropes having 12-inch square mirrors.

In the triangulation across the Mediterranean Sea between Spain and Africa, the length of the longest line used was 168 miles, while in the great trigonometric survey of India the longest side of any of the main triangles was 63 miles. On the other hand, a large number of Himalayan peaks were observed from occupied triangulation stations of the Indian survey and the distances to many of these peaks exceeded 200 miles. In the latter work the pointings of the instrument were on the visible outlines of the peaks against the sky and no observations were made from the mountains themselves. It is believed that both lamps and heliotropes have been used in the observations outside of the United States.

With the recent improvement of the electrical signal lamp observations for the most important triangulation in this country are made almost entirely at

night. This lamp is patterned after the automobile headlight, with the exception that the bulbs have a filament concentrated as nearly to a point as practicable and located at the focus of the lens, the idea being to concentrate as much as possible of the reflection in a pencil of light, the bright part of which hardly exceeds an arc of two degrees. The air is less disturbed at night and there is less dust and smoke in it; in fact, the observing conditions are at their best in the early part of the night, unless in a section susceptible to nightly fog. With the electric signal lamp, observations were made in 1921 from a station on San Francisco Peak to Ord's Peak and to Green Mountain, Arizona, distances of 153 and 151 miles, respectively, while observations were made on two other lights at distances of over 100 miles simultaneously with the others. All these lights could be seen with the unaided eye throughout the period of observations. (The distances given are all in statute miles.)

Most of the foregoing refers to instrumental observations on artificial objects and not to what can be seen with the unaided eye. On this question there is a great amount of confusion and also some diversity of opinion. There are numbers of cases on record where objects have allegedly been seen with the naked eye much farther than the distances quoted. Our Pike's Peak in Colorado is reputed to have been seen at great distances by travelers in the prairie sections east of it. Travelers in Tibet claim to have seen Mt. Everest from points found to be 400 miles distant, and it has been said that from San Francisco Peak in Arizona one can see into six states and over considerably more than half the entire state of Arizona. Mathematically, it is impossible to see such great distances as these last few, as the curvature of the earth alone precludes such seeing under ordinary conditions, but

we will reserve our doubts somewhat for the future, as it is also well known that certain atmospheric conditions do present strange phenomena and we are thereby able to see objects which are ordinarily considered invisible, as we are about to relate.

An authentic example of this is on record. During the summer of 1911, the officers of the ship *Explorer*, 36 hours out in the Gulf of Alaska from Dixon Entrance to the Shumagin Islands, sighted a group of clear-cut snowclad peaks to the northeastward. The peaks were watched carefully for about 30 minutes, becoming very sharp and distinct and, after examination by compass bearings, were identified as the Fairweather Mountains, which were at a distance, scaled from the map, of 330 miles. The altitude of the highest peak as thus seen was measured and found to be seven minutes above the horizon. Under ordinary conditions the earth's curvature would have obscured the mountains at a distance of about 150 miles. The vision at this long distance can only be explained by refraction, which is known to be very extreme under certain atmospheric conditions in that locality. Refraction is the bending of paths of light passing through layers of atmosphere of different densities. Its tendency is to make the distant object appear too high. Thus we see the sun rise before it actually does.

Another case of unusual refraction was experienced by one of the field parties of the Coast and Geodetic Survey engaged in triangulation in southern Texas in 1917. When first occupying station Towne, which was in the afternoon, the observer noted that station Peters, some 10 miles distant, was obscured by a ridge about midway between the two stations, though to what extent could not be determined. Refraction is greater at night than during the day and, as had been confidently hoped, the

light on Peters came out at the usual time at which the light-keepers tend their stations. Observations were begun on this station along with the others, but in a short time the brilliancy of the light began to fade and soon it was lost to view, just after the observations had been completed. It was hoped that the observations in the opposite direction over the line might be made in a similar manner, but no light at all could be seen. After three full days of effort spent in trying to see this light, it finally became necessary to raise both the instrument at one end of the line and the light at the other end 15 feet before observations could be made on what even then was a very dim light due to its grazing the intervening ridge.

Visibility between points on the earth's surface is limited by the curvature of the earth and the meteorological conditions along the line of vision. Curvature, combined with normal refraction, is approximately 5,700 feet at a distance of 100 miles, 22,900 feet at 200 miles and 51,500 feet at 300 miles, and most of the long lines over which observations have actually been made could be observed only by reason of the high mountain elevations with low country intervening. It is well known that dust, haze, smoke and fog greatly obstruct vision, and also that some sections of the country are freer from these than others. It is erroneously thought by some that one can see through these media, at least to some extent, by using powerful telescopes or binoculars; also that one can penetrate distance, and by that means, see much farther than it is possible to see with the naked eye. A telescope has no such magic power, as any particles of matter held in suspension in the air are also magnified in proportion to the power of the telescope, and under many of the extreme conditions such an instrument is almost useless. It is well known among experienced observers that it is

nearly always possible to see the outline of the land where a signal is located with the unaided eye at any time, except at night, that it is possible to make observations. It is generally true that when an object can be seen with a telescope at any distance, an object may also be seen with the naked eye at the same distance, provided the object is large enough. The distinction as regards vision with or without the aid of a telescope is therefore concerned almost entirely with size.

A slightly different case, and one of very common occurrence, is seeing through a boiling atmosphere or one of intense heat waves. When this boiling is intense or close to the observer, it very plainly affects seeing even with the naked eye. With the telescope the motion of the air is magnified and the object under examination may be, under extreme cases, so distorted as to be utterly unintelligible.

Visibility varies greatly with the locality and the meteorological conditions and is consequently rarely constant over any long period. That region in North Carolina and Tennessee so appropriately named "The Great Smoky Mountains," now set aside as a national park, is a region where the average limit to the length of sight is believed to be between 20 and 25 miles. It is very doubtful if 50-mile lines could be observed for as much as 10 per cent. of the time. On the other hand, many sections of the

Middle West have such a constantly clear atmosphere that the average limit of visibility is probably between 75 and 100 miles, and frequently much more than this. The condition of the atmosphere has a great influence on visibility, which improves as the elevation increases. In regions near cities or industrial centers visibility is greatly limited by smoke and dust, and near most of our coast line by fog or vapor.

Like almost any specialized work, the expert observer develops his power of understanding and interpretation of what he sees to a fine art. He can observe when others see nothing. It is only another form of that old question "How much do we know of what we see?" One man on the water may view an approaching storm, merely interested in the play of the wind on the water and the fanciful patterned waves thus formed, while another man sees the approaching storm in relation to its probable intensity, the effect it may have on his craft and the havoc it may play on shore. This question of seeing great distances, or in another form, the distances we can see, is therefore a constantly varying quantity. With study one finds as many diverging view-points as with almost any question of the human mind, since any examination of the problem must take into consideration knowledge and experience, ability to interpret, and, in fact, the entire individual background.

A GEOGRAPHIC STUDY OF COSMIC RAYS¹

By Professor ARTHUR H. COMPTON
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In a recent review of the subject of cosmic rays, Dr. K. K. Darrow describes their study as "Unique in modern physics for the minuteness of the phenomena, the delicacy of the observations, the adventurous excursions of the observers, the subtlety of the analyses, and the grandeur of the inferences." These adjectives are aptly chosen. The cosmic rays are bringing us some important message. What this message may be, we have not, however, learned. Perhaps they are telling us how our world has evolved, or perhaps they are bringing news of the innermost structure of the atomic nucleus.

Attention both of scientific men and of the public was called forcibly to the importance of the studies of cosmic rays by Professor Millikan's suggestive theory of their origin, which he presented at the autumn meeting of this academy seven years ago. He developed the idea that the cosmic rays are produced during the formation of atoms in interstellar space, and presented evidence that this is one stage of a cyclic process through which the universe is continually passing. It will be worth while to dwell for a moment upon this theory and to describe other hypotheses that have been proposed regarding the nature and significance of cosmic rays.

Millikan based his theory on the assumption that the cosmic rays are electromagnetic radiations, or photons, similar in type to x-rays and gamma rays, but of shorter wave-length. This was a natural assumption, in view of the surprisingly great penetrating power which the cosmic rays were found to

possess. Considering them to be photons, it was possible to calculate the energy which each individual cosmic ray must have to give it the penetrating power observed in the experiments. On the other hand, he could also calculate the energy liberated by certain types of atomic processes. Thus, if an atom of helium is formed by the sudden combination of four protons and four electrons, the energy liberated is just that necessary to give a photon of penetrating power equal to the least penetrating cosmic rays. The protons and electrons would presumably occur in interstellar space in the form of hydrogen gas. Thus Millikan pictured helium as being formed by aggregations of hydrogen atoms in the intense cold of the space between the stars.

You will recall how Professor Millikan made this process of the formation of helium out of hydrogen one stage in a great cycle. In a similar process it was supposed that heavier atoms, such as oxygen and iron, were likewise formed. The resulting atoms were supposed to come together under gravitational force to produce nebulae and stars. These, in turn, would radiate their energy in the form of photons of electromagnetic radiation. During their passage through space it was supposed that in some unknown manner the energy of these photons would be transformed into electrons and protons, which would be the start of a new cycle.

Immediately following this hypothesis of Millikan's, Sir James Jeans suggested the alternative view that these rays result from the annihilation, rather than from the transformation, of matter. Jeans noted that if they are photons, the

¹ Address before the National Academy of Sciences at Ann Arbor on November 14, 1932.

most penetrating part of the cosmic rays should have just the energy that would be liberated by the sudden coalescence of the electron and proton in a hydrogen atom. That is, whereas Millikan pointed out that the least penetrating cosmic rays have the energy to be expected from the formation of helium atoms out of hydrogen, Jeans found that the most penetrating cosmic rays correspond to the annihilation of hydrogen atoms themselves.

Recently an interesting theory regarding the nature of cosmic rays has been proposed by a young French physicist, Dauvillier. This is not based on the idea of cosmic rays as photons, but rather on the conception that they are electrons shot toward the earth from the sun. This theory is thus somewhat similar to that of Störmer, in which he accounts for the aurora borealis as due to electrons thus shot toward the earth. Dauvillier finds evidence for strong electric fields existing in flocculi on the surface of the sun, estimated at thousands of millions of volts. These powerful electric fields, he supposes, serve to eject the electrons in all directions, some of which would approach the earth. Near the earth they would be affected by the earth's magnetic field and cause at the same time the auroral displays, which are known to be concentrated near the earth's magnetic poles.

It thus becomes clear that before the cosmic significance of these rays can be interpreted, it is necessary for us to test whether the rays are indeed of the nature of photons or of electrons. That is, speaking more generally, are they electrically neutral particles of radiation or some kind of charged particle, such as electrons or protons?

METHODS OF DISTINGUISHING BETWEEN CHARGED AND UNCHARGED RAYS

Among the most important methods of distinguishing whether cosmic rays

consist of charged or of uncharged particles are the following:

(1) A study of the absorption of the cosmic rays. It is possible to calculate the absorption of electromagnetic radiation in various materials on the basis of a quantum theory. At present the most satisfactory form of this theory is perhaps that proposed by Klein and Nishina some three years ago. Though it is doubtful whether this theory can be considered as a final one, it has been tested experimentally using short wave-length gamma rays, and has been found to fit the experiments reasonably well. There is, nevertheless, danger of error in the use of this formula when extrapolating to wave-lengths much shorter than the gamma rays by which it has been tested. Assuming, however, the validity of the formula, it is possible to calculate what the wave-length must be for a ray of any measured penetrating power. It is on the basis of such an analysis that Millikan's and Jeans' theories have been developed.

The absorption of high-speed electrons can be calculated with a higher degree of certainty on the basis of a formula developed originally by J. J. Thomson and extended to very high energies by Bohr, Swann and others. According to this theory, when an electrified particle passes through matter with a speed closely approximating that of light, its energy is spent in giving impulses to the electrons past which it moves. The effect of these impulses is to produce ions along the path of the high-speed electron. Experiments with x-rays have shown that over a wide range of energies of the high-speed ionizing particle the work required to produce a pair of ions remains nearly the same, about 30 electron volts. Thus the theories of the absorption of these high-speed electrons can be checked by measuring the number of ions produced along the path of an individual ray. Such measurements indi-

cate that the theory in its present form predicts with considerable accuracy the rate at which energy is dissipated by electrons moving with speeds as great as 5×10^8 equivalent volts. It is thus possible to make a definite estimate of the energy of a high-speed electron which will have any assumed penetrating power.

Cosmic rays vary in penetrating power from the comparatively soft ones found only at high altitudes to the very penetrating rays measured by Regener in the deep waters of the Lake Constance. If we suppose that the cosmic rays are electromagnetic in character, their energies should lie between 3×10^7 and 2×10^9 electron volts to give the observed penetrations. If, on the other hand, these rays are high-speed electrons, their penetration corresponds to energies of from 2×10^9 to 7×10^{10} electron volts.

Then comes the problem of accounting for rays having these tremendous energies. The most energetic process that has been proposed for the production of electromagnetic rays is the sudden annihilation of an electron and a proton, as in an atom of hydrogen. This process releases an energy of about 10^9 electron volts. In order to account for the most highly penetrating cosmic rays, then, it is supposed either that Regener's experiments or Klein and Nishina's formula may be somewhat in error for these very penetrating rays, and that the difference of a factor of two between the energy estimated from the experiments and that calculated from the mass of the hydrogen atom really represents a reasonable agreement. On the other hand, the disparity of a factor of seventy between the energy liberated by the annihilation of a hydrogen atom and that required to give an electron so great a penetrating power is certainly greater than the possible errors involved. This would mean that these very penetrating cosmic rays can

not be electrons resulting from the destruction of hydrogen. Those who propose the high-speed electron theory, therefore, look to some other source for the energy. Thus, as we have seen, Dauvillier proposes strong electric fields in the surface of the sun. Others have suggested large potential differences in different parts of interstellar space.

(2) There is, however, another aspect of the absorption problem which has been emphasized by Millikan and by Darrow. If the cosmic rays consisted of a homogeneous beam of electromagnetic radiation passing perpendicularly through the earth's atmosphere, we might expect the rays to be diminished in intensity according to a simple exponential law. That such a simple exponential law is not in fact followed is obvious from all the experiments that have been performed. The difference at low altitudes is of the type that might be expected if the incident rays consist of a spectrum of radiation of definite wave-lengths. There is also the fact to be considered that the rays do not strike the earth's surface perpendicularly. They are, rather, moving in all directions.

There is, however, a definite type of difference that may occur in the absorption of photons as compared with the absorption of electrons in the earth's atmosphere. If the rays are of a purely photon type when they strike the surface of the atmosphere, they should produce almost no ionization in an ionization chamber placed at that point. This is because the ions in such a chamber result directly from the passage through the chamber of high-speed electrons or other charged particles. Such high-speed electrons are produced by photons when the photons themselves are absorbed by an atom. The usual result of such absorption is the ejection from the absorbing atom of an electron possessing large part

of the photon's energy and moving usually in nearly the direction of the original photon. Thus, only after the photons have traversed a layer of air so thick that a large portion of their energy will have been transformed into the high-speed electrons, will it become possible to measure the rays by means of an ionization chamber. It thus becomes apparent that near the surface of the atmosphere photons entering the air should produce little effect; but as the ionization chamber is brought lower down into the air, there will be some position at which the intensity of ionization will become a maximum. At lower altitudes the cosmic rays will have become so strongly absorbed that the ionization will become less, and will from there on be reduced in a nearly exponential manner as the chamber is brought to lower and lower altitudes.

High-speed electrons, on the other hand, produce ions of nearly the same number per unit path until they have reached nearly the end of their range. If we suppose that the rays striking the surface of the earth's atmosphere are purely electronic in form, ionization should thus be strong at the surface of the atmosphere. We should expect the current in an ionization chamber to remain approximately constant if the chamber should be carried downward from the surface of the atmosphere, until it reaches such depths that an appreciable number of the original electrons are stopped by absorption in the atmosphere.

If the rays approaching the earth are photons, an ionization chamber should accordingly record almost no current near the top of the atmosphere. If the incident rays are electrons, the current in the chamber should approach a gradual maximum near the top of the atmosphere. It is in the attempt to see whether either of these alternatives is in

accord with fact that the recent high altitude mountain and balloon measurements have been made. These experiments, as we shall see, have supported the incident electron view.

(3) An experiment which was at first thought to give decisive evidence that the cosmic rays consist of electrons was carried out some three years ago by Bothe and Kolhörster. We have remarked that whatever may be the character of the primary cosmic rays, the ionization currents that are observed in our experiments are directly due to ions produced by high-speed electrical particles. It is possible to devise an electroscope so sensitive that it will respond to the ionization produced by a single such high-speed particle. Such an instrument is known as an ion counter. Bothe and Kolhörster arranged two such counters, one over the other, as indicated in Fig. 1.

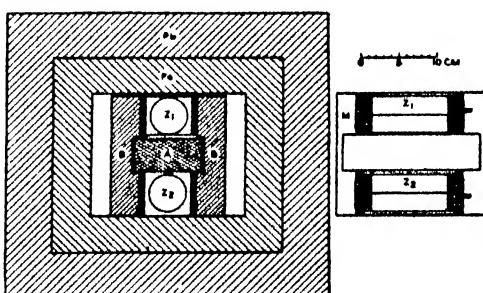


FIG. 1. BOTHE AND KOLHÖRSTER APPARATUS

FOR MEASURING THE ABSORPTION OF PARTICLES PASSING BETWEEN TUBES Z_1 AND Z_2 , THROUGH THE BLOCK OF GOLD A.

The two counters were so connected that if ions were produced simultaneously in both chambers, a record would be produced. No record, however, would result from ions formed in only one of the two chambers. Thus, if a high-speed particle should pass directly through both chambers it would be recorded by their instrument. It was found that if

one counter was placed over the other, as in this drawing, frequent coincidences were observed. If, however, they were placed at an equal distance, but side by side, such coincidences were rare. This indicated that the high-speed particles that were being recorded were traveling in a nearly vertical direction.

Bothe and Kolhörster now placed between their counters a heavy block of gold to absorb and, if possible, stop the high-speed particles from passing through both counters. If the particles were thus stopped there should, of course, occur no coincident impulses in the two chambers. It was found, however, that a block of gold as thick as four centimeters still allowed most of the particles to pass through. The experiment has more recently been repeated by Rossi, using a block of lead 30 inches thick, and he still observed a considerable fraction of the coincident impulses that occurred with no absorbing screen. When the absorbing block was placed over the upper counter the reduction in coincidence counts was almost the same as when placed between the two counters. This meant that the absorption of the high-speed particles passing through the two counting chambers was very nearly the same as the absorption of the cosmic rays which produced the high-speed particles.

The most obvious interpretation of this experiment was to suppose that the high-speed particles that were being counted were the cosmic rays themselves. Millikan pointed out, however, that what the experiment really showed was that these high-speed particles are absorbed at very nearly the same rate as are the cosmic rays, and he suggested that at very high energies the rate of absorption of a photon may be almost indistinguishable from the absorption of the recoil electrons which it knocks out of the atoms through which it passes. A recent de-

tailed study by Heisenberg shows, however, that it is very difficult to reconcile Millikan's suggestion with the theory of absorption of photons and electrons. If Millikan's suggestion were correct, it would mean that an electron having the same energy as a photon should be absorbed less rapidly by air. The theories of absorption seem to predict definitely that the electron must always have the greater absorption. These experiments with the counting chambers thus give evidence so direct in favor of the hypothesis of cosmic rays as electrons that this possibility must be given careful consideration.

(4) Perhaps the most direct method of distinguishing between charged and uncharged particles in motion is to see whether they are deflected by a magnetic field. By this method, for example, it was first shown that cathode rays are negatively charged, resulting in the identification of the electron.

Several investigators have attempted to deflect cosmic rays by means of great magnets. Among the first of such attempts was one by Curtis, in which he studied the coincident discharges in a pair of ion counters when a powerful electromagnet was placed between the counters. He observed a small but definite effect. Later experiments by Mott-Smith and at about the same time by Rossi, both of whom allowed the cosmic rays to traverse an iron core of the electromagnet, showed no effect. Within the past year Anderson, working with Millikan at Pasadena, has studied the tracks produced by cosmic rays in a cloud expansion chamber.

Fig. 2 (see p. 81) shows a typical photograph. There can be seen a fine line of fog droplets marking the trail of a particle which traversed the chamber at high speed. The slight curvature is due to the action of the powerful magnetic field in which the chamber was placed.

Supposing that the particle is moving downward, the direction of curvature is appropriate to a negatively charged particle. There also occur in these photographs similar tracks which seem to be due to positively charged particles. There is thus an effect produced by a magnet on the cosmic rays.

It is not clear from experiments of this kind, however, whether the trails which are being photographed are those of the primary cosmic rays or whether they may be secondary electrons produced by the primary rays. Thus, we have not been able by such experiments to determine the nature of the primary cosmic rays themselves.

(5) For studying the original rays, it would be necessary to have a magnet so large that it would affect the rays before they reach the earth's atmosphere. This, however, is exactly what we have in the earth itself, which of course acts as a huge magnet. With this in mind, several investigators have made studies of the strength of the cosmic rays at different points on the earth in the attempt to find whether these rays are affected by the earth's magnetic field. Theoretical studies by Störmer and Epstein have shown that if the cosmic rays are electrons shot at the earth in all directions from remote space the earth's magnetic field will prevent all the rays from striking its surface, except in the neighborhood of the magnetic poles. Even for initial energies as great as 10^9 electron volts the electrons would strike the earth only within some 30° of the magnetic poles. Such calculations suggested that the effect of the earth's field, if any, should be most strongly observed in the polar regions.

Accordingly, Millikan took his cosmic ray electroscope from Pasadena to Churchill on Hudson's Bay, near the north magnetic pole. Bothe and Kolhörster took their counting chamber

from Hamburg up to Spitzbergen and back. Kerr Grant sent Kennedy from Australia to the Antarctic with a cosmic ray counting chamber. Corlin traveled in different parts of Scandinavia, where the earth's magnetic field changed in intensity. Only one of this first group of investigators studied the ray near the equator. This was Clay of Amsterdam.

On bringing together their results, it was found that although Clay and Corlin had both seemed to detect effects which they considered greater than experimental error, the other investigators failed to find any detectable differences that could be ascribed to the earth's magnetic field.

WORLD SURVEY OF COSMIC RAYS

Before our theories regarding the origin and significance of the cosmic rays could be developed further, it was clear that we must, if possible, find out their nature. Though Bothe and Kolhörster's double counter experiment had given a strong indication that the rays were electrical in character, the failure in these preliminary experiments to find any definite connection between the earth's magnetic field and the intensity of the cosmic rays in different parts of the earth left their nature in doubt. It seemed that by far the most significant study that could be made of this question would be an extensive survey of the strength of the cosmic rays in different parts of the earth. Some fifteen months ago we accordingly undertook such a survey with the support of the Carnegie Institution. Our principal objectives were, (1) to obtain as extensive information as possible regarding the distribution of cosmic rays over the earth; (2) to study the variation in intensity of the cosmic rays with altitudes in different locations; and (3) to see whether there exists any difference between the cosmic ray radiation in daytime and at

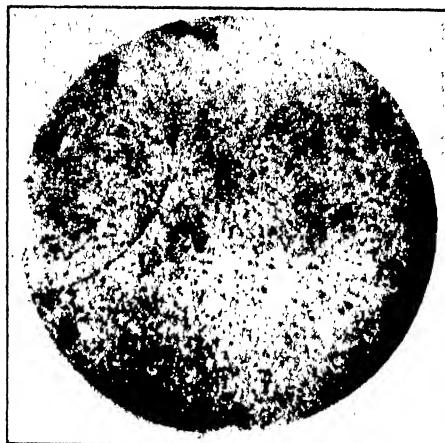


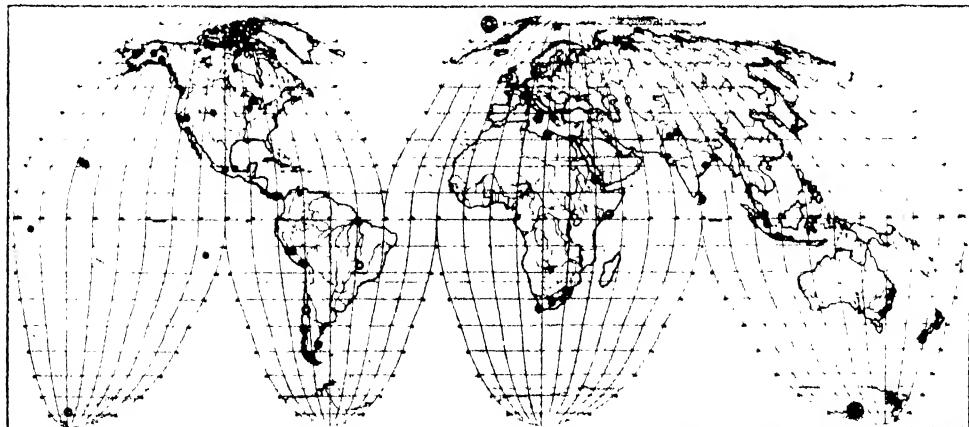
FIG. 2. ANDERSON'S PHOTOGRAPH
OF THE PATH OF AN ELECTRON ASSOCIATED WITH COSMIC RAYS.

night. It was hoped that the information thus obtained, added to that which had been gathered by other methods, would enable us to give a reasonably definite answer to our question as to the nature of the rays.

It was, of course, necessary in a program of this kind to get the extensive cooperation of a large number of physicists. Our invitations to join this work met with an enthusiastic response. In

order to make a reasonably complete survey within a brief period, the globe was portioned into nine regions, each of which was assigned to a different investigator. In charge of these various expeditions were the following men, each of whom has been responsible for the results obtained by his own party:

(1) Professor Ralph D. Bennett, of the Massachusetts Institute of Technology, whose



-Prepared by J. Paul Goode

FIG. 3. SOLID CIRCLES

ARE STATIONS WHERE MEASUREMENTS BY OUR ASSOCIATED EXPEDITIONS HAVE BEEN COMPLETED.
OPEN CIRCLES REPRESENT PROJECTED MEASUREMENTS. MEAN MAGNETIC POLES IN CIRCLES.
LOCAL POLES WITHOUT CIRCLES.

party has studied Alaska, California and Colorado.

(2) Dr. E. O. Wollan, of the University of Chicago, who has made measurements in Chicago, Spitzbergen and Switzerland.

(3) Dr. D. la Cour, director of the Danish Meteorological Survey, whose expedition is now working in northern Greenland at the north pole of the earth's uniform magnetization.

(4) Mr. Allen Carpe, research engineer of the American Telephone and Telegraph Company, whose ill-fated expedition made measurements on Mount McKinley, Alaska.

(5) Professor J. M. Benade, of Punjab University, who has worked in India, Ceylon, Java and Thibet.

(6) Professor S. M. Naude, of the University of Cape Town, now working in South Africa.

(7) Mr. P. G. Leditz, in charge of the Carnegie Magnetic Observatory at Huancayo, Peru, who is just preparing to start from Peru around Cape Horn and back by way of Brazil to the United States.

(8) Admiral Byrd and his associated physicist, Professor Pouiter, of Iowa Wesleyan Uni-

versity, who plan to continue these studies in Antarctica.

(9) My own branch of the expedition, which has worked in Switzerland, Colorado, Hawaii, New Zealand, Australia, Peru, Panama, Mexico, northern Canada and northern United States.

Accompanying these leaders there have been some fifty other cooperating physicists, who have worked intensively for periods of from a few days to several months to help in completing the survey. A glance at the world map will indicate how these expeditions have attempted to cover representative portions of the earth's surface.

Following the lead of earlier investigators and the theoretical predictions of Epstein, the most detailed attention of these expeditions was directed to the north and south magnetic polar regions. If one knew beforehand the result of an experiment there would be little value

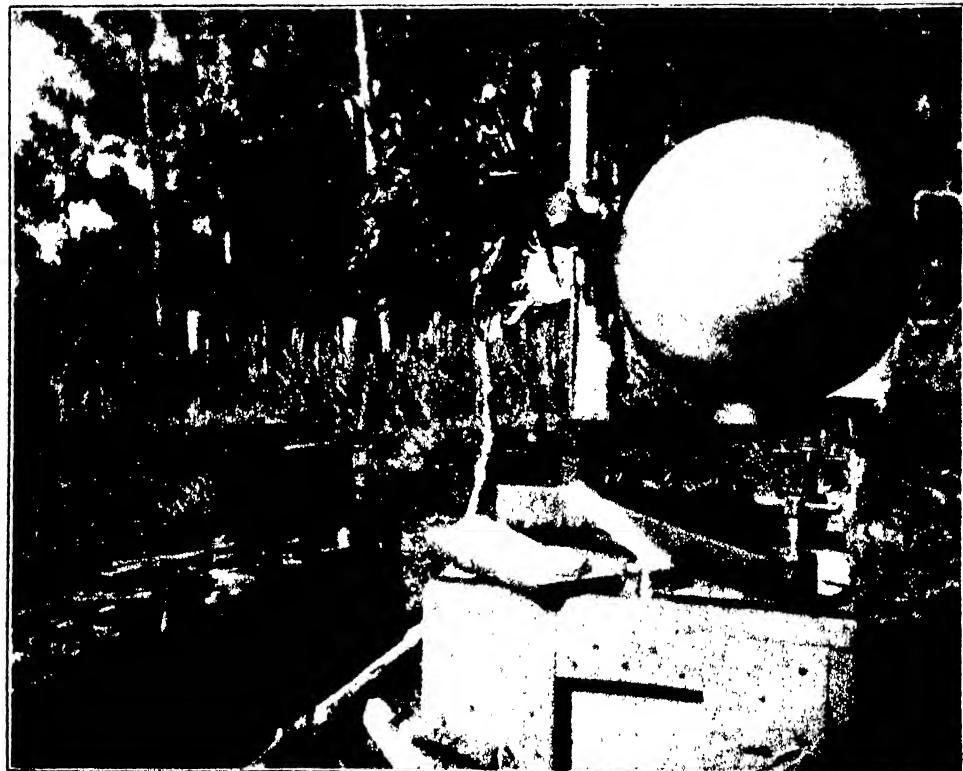


FIG. 4. COSMIC RAY APPARATUS AS USED IN FIELD MEASUREMENTS.

in performing that experiment. Thus, in planning this work, had we known that the interesting results would be found near the equator, our apportionment of the various trips would have been made in a very different manner. Our measurements showed very little, if any, variations near the magnetic poles, but quite marked differences in the equatorial regions.

The apparatus used in this survey is shown in Fig. 4 on page 82. It consists of a spherical steel ionization chamber, filled with argon gas at thirty atmospheres pressure, and connected with a Lindemann electrometer, which measures the ionization current. Heavy spherical shells of lead and copper protect the ionization chamber from gamma rays from local sources. For standardizing the measurements, a capsule containing a small quantity of radium is placed one meter from the center of the ionization chamber. The gamma rays entering the chamber serve as a standard relative to which the cosmic rays can be measured at any location. There is always a certain amount of ionization due to radioactivity in the ionization chamber itself. For three of the eight sets of equipment this has been measured by carrying each set into a tunnel where it was shielded by 1,000 feet or more of rock.

In Fig. 5 is shown a group of curves representing the variation of the intensity of the cosmic rays with altitude as we have found them in different locations. In this slide has been included all the data so far reported by our various expeditions. It will be seen that all the curves have a similar shape, representing rapid increase in intensity with altitude. It will be noticed also, however, that the lowest curves are all taken in tropical regions and the highest curves in temperate or polar regions. Knowing the shape of the altitude intensity curves, the value at sea-level

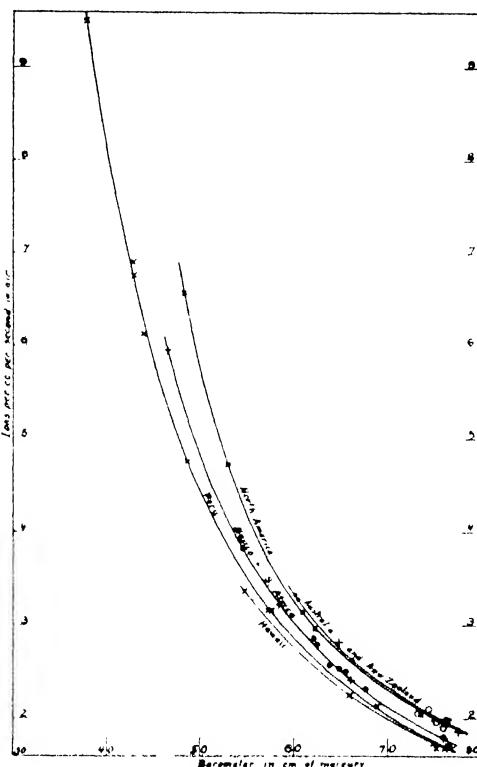


FIG. 5. INTENSITY OF COSMIC RAYS AT VARIOUS ALTITUDES AS OBSERVED IN VARIOUS PARTS OF THE WORLD.

corresponding to the observed intensity at any level corresponding to the observed intensity at any other altitude can be estimated. Thus we can plot these data against the latitude if we reduce each observation to its equivalent value at some standard altitude, such as sea-level.

Fig. 6 shows the data, thus reduced to sea-level values, plotted against the geographic latitude. In general, it is clear that the low latitudes show less intensity than do the higher latitudes. There is, however, considerable variation from the smooth curve drawn through the experimental points. When, on the other hand, we plot the sea-level intensity against the magnetic latitude, as shown in Fig. 7, it will be seen that the data fall more nearly upon a smooth

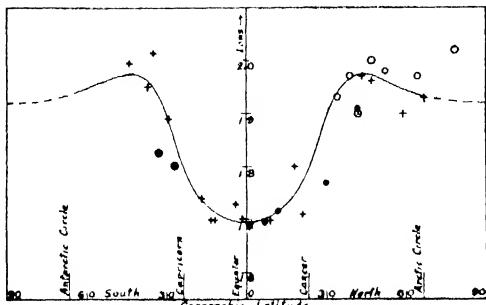


FIG. 6. INTENSITY OF COSMIC RAYS AT SEA LEVEL, AT LATITUDES FROM 44° S TO 78° N, AS MEASURED BY VARIOUS OBSERVERS, SHOWING MINIMUM NEAR THE EQUATOR.

curve. This magnetic latitude is taken as the distance from the magnetic equator drawn between the poles of the earth's uniform magnetization, and thus represents the effect of the earth's field as observed at some distance from its surface.

It would seem from these data that a definite variation occurs in the intensity of cosmic rays for different positions in the earth's magnetic field. Though in northern and southern latitudes the intensity would seem to be very nearly uniform, in equatorial regions there is a marked minimum. What interpretation can be given to such a variation? It is obvious that such a magnetic effect must mean that there are electrically charged particles

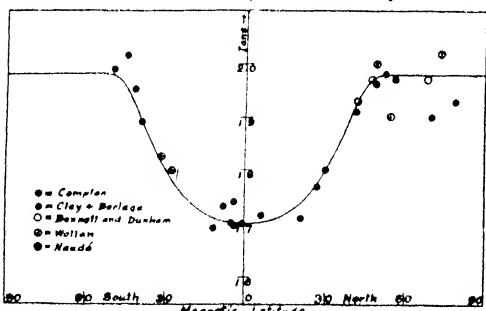


FIG. 7. WHEN PLOTTED AGAINST THE MAGNETIC LATITUDE, THE INTENSITY OF THE COSMIC RAYS FALLS MORE ACCURATELY ON A CURVE THAN WHEN PLOTTED AGAINST GEOGRAPHIC LATITUDE, AS IN FIG. 6.

associated with the cosmic rays. Are these particles, however, the primary rays or secondary rays produced by the primary rays?

SIGNIFICANCE OF THE VARIATION WITH MAGNETIC LATITUDE

A definite answer to this point would seem to be given by a consideration of the conditions under which the earth's magnetic field can produce an appreciable curvature in the path of a high-speed electron. If such curvature is to be appreciable, the distance that the particle travels before being stopped by the earth's atmosphere must be sufficiently large. If this range is short compared with the radius of curvature of the path of the particle, the path will be nearly a straight line, that is, the earth's magnetic field will have no appreciable effect. Now the path of an electron moving at high speed in a magnetic field has a radius of curvature proportional to the energy. On the other hand, the range in air of a high-speed electron is likewise, according to current theories, proportional to the energy of the particle's motion. Thus for these high-speed particles there is a definite ratio of range to radius of curvature, which is independent of the particle's energy. At atmospheric pressure it can be shown that the radius of curvature should be about 25 times the range of a high-speed electron. This would mean that at atmospheric pressure the curvature produced in the path of an electron by the earth's magnetic field should be negligible. If, however, we go to an altitude of say 15 miles where the density of the earth's atmosphere is about $1/25$ of that at sea-level, the range of an electron should be about equal to its radius of curvature, and under these conditions the earth's magnetic field should have an appreciable effect. It thus becomes evident that a variation in intensity of the cosmic rays

with the earth's magnetic field means that associated with these rays are electrons (or at least electrified particles) which originate at an altitude of not less than 15 miles.

Supposing that it is these electrons originating high in the earth's atmosphere which are detected by our ionization chambers at the earth's surface, an investigation of the energy necessary for the particles to penetrate the atmosphere indicates that they must start with an energy not less than several billion electron volts. This would give them a radius of curvature in the earth's magnetic field of the order of at least some hundreds of miles. Thus, our magnetic data can be satisfactorily explained if we suppose that the cosmic rays originate as high-speed electrons high in the earth's upper atmosphere. Such a region of origin would be approximately the same as that at which the auroral displays occur. Associated with such high-speed electrons there would also be produced rays of the photon type; that is, x-rays of very short wave-length. These rays might well constitute those which are observed by Regener at very great depths in water.

A possible alternative to this interpretation would seem to be that the electrons reaching the earth enter from remote space with energies so great that they are not very strongly affected by the earth's magnetic field. From Epstein's calculations this would mean that they must have an initial energy of the order of 10^{10} electron volts.²

VARIATION WITH ALTITUDE

In various locations our expeditions have made a special study of the variation

² Since this was written, the manuscript of a new theory by Le Maître and Vallarta has been shown me, from which it appears that electrons of less energy than 10^{10} electron volts can reach the earth from remote space. The predictions of their theory, based on electrons from remote space, agree very well with the data shown in Fig. 7.

in the intensity of cosmic rays with altitude. Perhaps the most satisfactory results have been those obtained in Peru and in Thibet. Fig. 8 shows a compari-

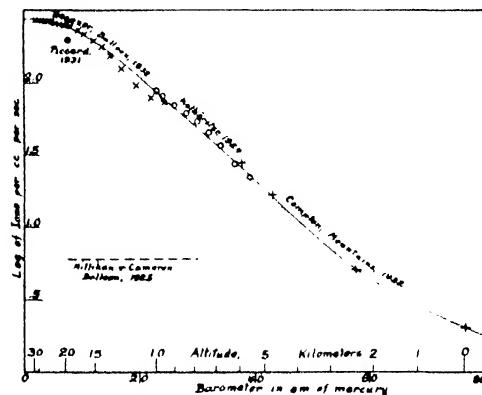


FIG. 8. INTENSITY OF COSMIC RAYS AT HIGH ALTITUDES, SHOWING ASYMPTOTIC APPROACH TO MAXIMUM AT SURFACE OF ATMOSPHERE, AS EXPECTED IF COSMIC RAYS ARE IONIZING PARTICLES.

son of our data obtained at two different locations in Peru with those found recently in the balloon flights of Piccard and Regener. For convenience the intensities are plotted logarithmically. If the rays are homogeneous and have a definite absorption coefficient the data on such a plot should lie on a straight line. An upward curvature would indicate a lack of homogeneity of the incident rays. That is, some would be of a more penetrating type than others. A downward curvature would mean that the rays are not absorbed in the statistical manner appropriate to photons or electromagnetic radiation. It is clear from this figure, as Regener has pointed out in connection with the result of his balloon flight, that at very high altitudes the intensity of the rays approaches a constant value such that for appreciable differences in air pressure there is no appreciable change in the intensity of the cosmic rays.

A consideration of the possible interpretation of this result is of interest. If we suppose that the cosmic rays enter the earth's atmosphere as photons, any

secondary electrons that may have been associated with them will have been removed far above the atmosphere by the action of the earth's magnetic field. We should thus have a beam of pure photons entering the atmosphere. As has been indicated above, at the surface of the atmosphere these photons will produce very little ionization. The ionization current should rather approach a maximum at a depth in the atmosphere at which the cosmic rays are about half absorbed, and should then gradually diminish in intensity as sea-level is approached. Some early sounding balloon measurements of Millikan and Bowen indicated that such an effect did indeed occur, and this was used as evidence for the photon character of the rays. Our high mountain experiments, however, confirm the more recent balloon experiments as indicating that no high altitude maximum, such as these early experiments suggested, exists. This would seem to rule out the possibility that the cosmic rays can be photons entering the earth's atmosphere from remote distances.

If we suppose, on the other hand, that the cosmic rays are electrons entering the atmosphere from above, we should expect very much the kind of intensity altitude curve that is here shown. Thus, supposing that the cosmic rays consist of electrons originating more than a hundred miles above the earth's surface and going from there in all directions, the general characteristics of the intensity altitude curve can be readily accounted for.

This view is strongly supported by an observation of Piccard on his recent balloon flight. He had with him a pair of ion counters so arranged that it was possible to distinguish the direction from which the ions entered his gondola. He reports that within experimental error, which was in his case less than 1 per cent., there was no difference

between the number of rays passing horizontally and those passing vertically. This is in striking contrast to similar tests made at sea-level, where the number of cosmic rays traversing the counters when arranged vertically is greatly in excess of those traversing them when placed in a horizontal direction. This observation, Piccard believes, supports the view that the cosmic rays originate in the part of the earth's upper atmosphere where his balloon was floating.

DIURNAL VARIATION

Ever since the early studies of cosmic rays by Hess, the question of their constancy at different times of day has been discussed. Though the relatively large variations at one time noted by Kolhörster have since been attributed to statistical fluctuations, more detailed studies have almost always shown a very slight preponderance of the radiation in the daytime as compared with the night. According to Hess, this difference at sea-level is of the order of .3 to .5 per cent. Millikan has reported differences of the same order of magnitude, but considers them within experimental error. Along with our other studies, we have also made an investigation of this point, although our apparatus was not large enough to make measurements with the statistical precision that would have been desirable for the purpose.

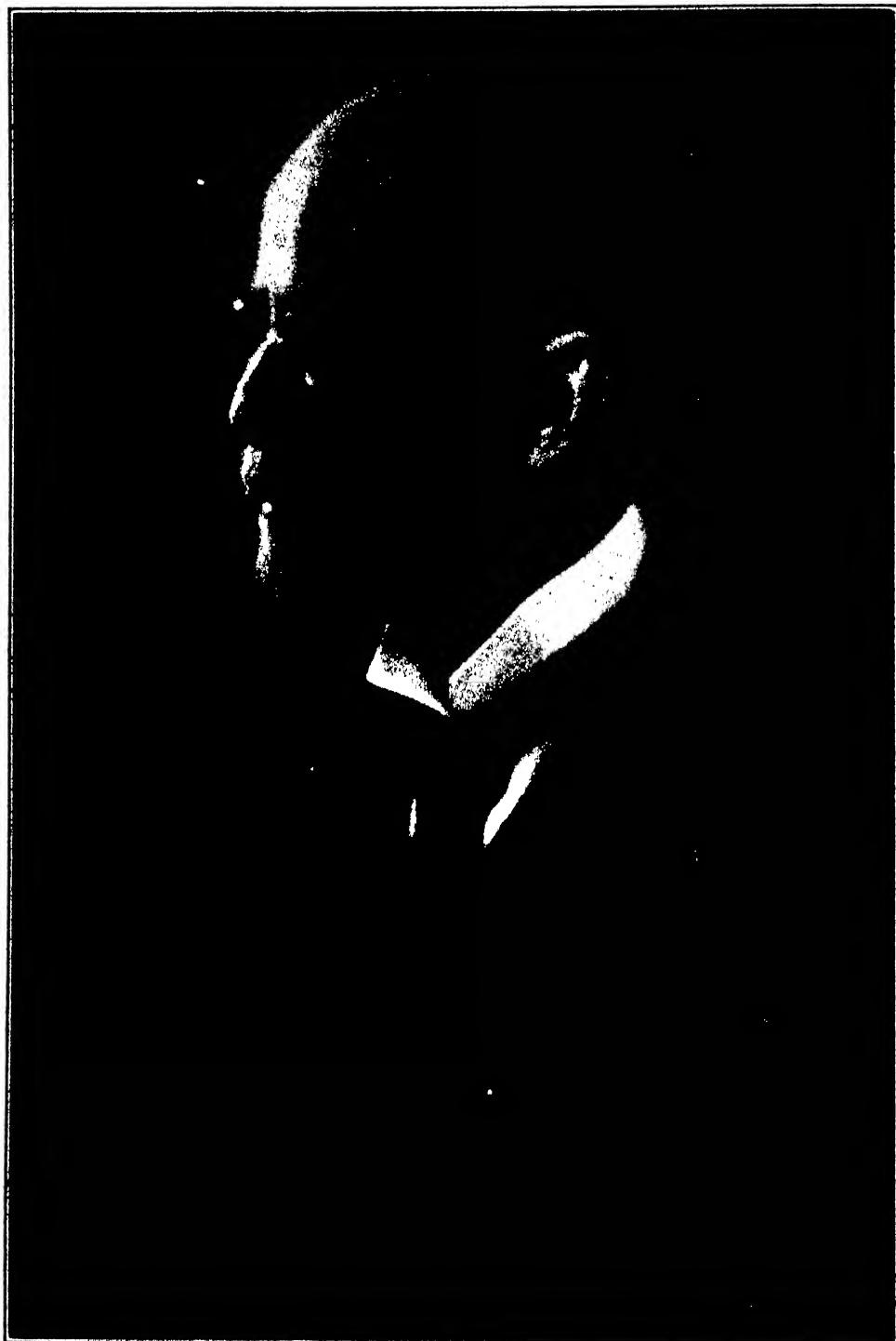
The result has indicated differences which are probably real and of higher magnitude than those found by other observers. Our measurements, however, have been made at higher altitudes. Professor Bennett and Dr. Dunham, working at the Arctic circle in Alaska, found no detectable difference whatever between day and night. In Colorado, at an altitude of 13,000 feet, we found an effect of the order of magnitude of one per cent. In Peru, at an altitude of 15,000 feet, the intensity in the daytime was about 2 per cent. greater than that

at night, though the probable error was comparable with the observed effect. This seems to indicate a maximum effect where there is a maximum contrast between day and night conditions.

Supposing that these observed differences are real, Ross Gunn has pointed out that they are of the type that would be expected due to the difference in the earth's magnetic field in the daytime and at night. He considers the effect as due to the diamagnetic characteristics of the ionized regions of the upper atmosphere, an effect which is greater at high altitudes than at relatively low altitudes. If this interpretation is correct, it would suggest that the origin of the electrons must be as high as a hun-

dred miles or more above the surface of the earth, thus confirming the estimate made on the basis of the effect of the earth's magnetic field.

It would thus appear that the data which have been obtained in this geographical study of cosmic rays may be satisfactorily explained if we suppose that the cosmic rays consist of electrons, originating at least some hundreds of miles above the surface of the earth. Whether the point of origin is in the earth's upper atmosphere or in remote space has not yet been determined. It seems necessary, however, to suppose that at least the major part of the rays consist of electrically charged particles rather than photons or neutrons.



DR. JOHN J. ABEL

EMERITUS PROFESSOR OF PHARMACOLOGY, THE JOHNS HOPKINS UNIVERSITY; PRESIDENT OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE PROGRESS OF SCIENCE

THE ATLANTIC CITY MEETING OF THE AMERICAN ASSOCIATION

ALWAYS mindful of its responsibilities toward those whose activities are concerned with the more or less highly specialized lines of science, the association of late years more and more has come to serve as a forum for the discussion of the broader bearing of scientific truths in their relation to human welfare and to human labors.

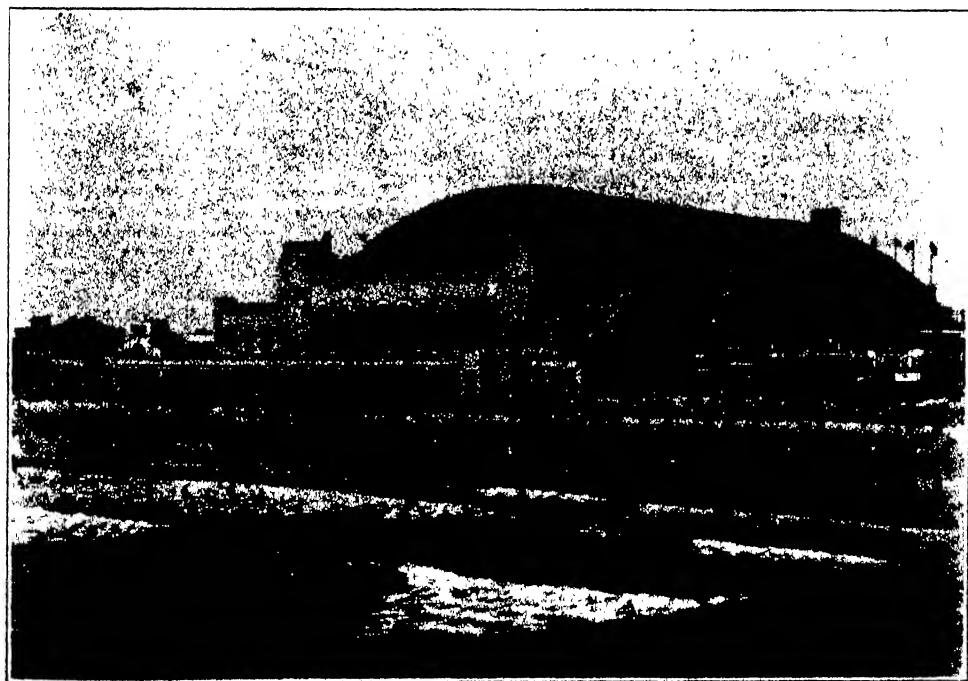
Progress in science is dependent upon two interallied factors. First of all, facts must be determined. But dissociated and disconnected facts, though always interesting, are of little value. In order to become of value, facts must be correlated and coordinated and assigned to their proper place in their relation to other facts, becoming thereby an integral part of the structure of science as a whole.

The proper appreciation and allocation of the facts accumulated by work

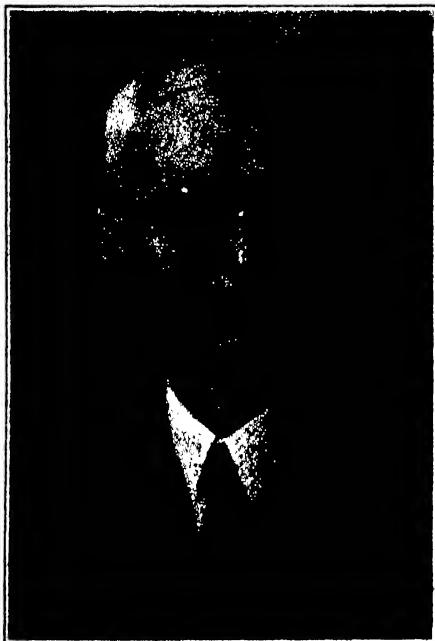
in the specialized lines of science is hastened by the critical examination and discussion of these facts, and their broad dissemination. Once properly appraised, it becomes possible to apply them to the good of the people as a whole.

The accumulation of the basic facts of science and their exposition and discussion for the most part falls within the scope of one or other of the one hundred and thirty-seven societies, representing all fields of science, which are affiliated with the association. Many of these societies will meet with the association at Atlantic City. The programs of those that will meet at Atlantic City are both unusually full and exceptionally interesting.

In addition to the more or less strictly technical papers there are included in the programs of most of the sections and societies addresses of more general scope,



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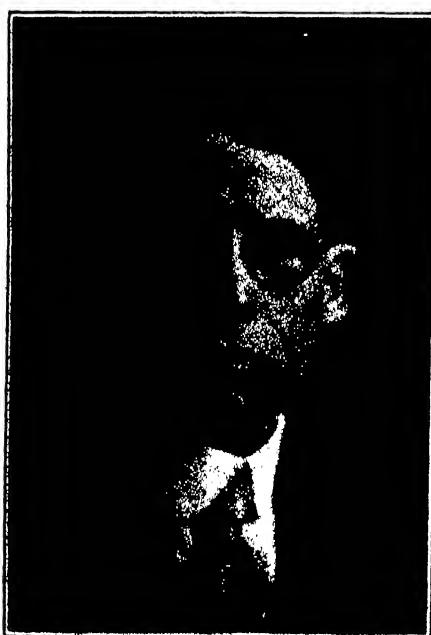
DR. HOWARD H. MITCHELL

PROFESSOR OF MATHEMATICS, UNIVERSITY OF PENNSYLVANIA; CHAIRMAN OF THE SECTION OF MATHEMATICS.



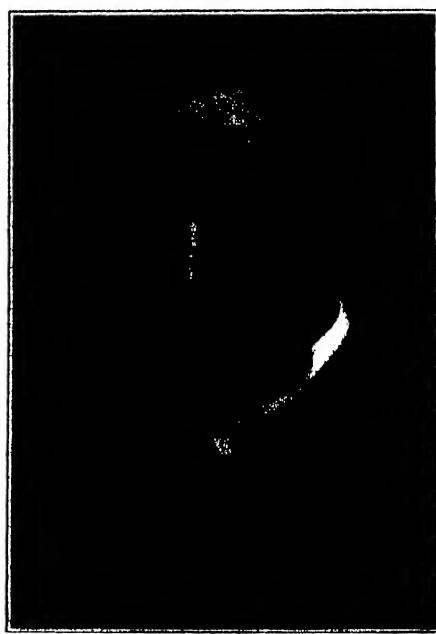
PROFESSOR FRANK C. WHITMORE

DEAN OF THE SCHOOL OF CHEMISTRY AND PHYSICS, PENNSYLVANIA STATE COLLEGE; CHAIRMAN OF THE SECTION OF CHEMISTRY.



DR. PAUL W. MERRILL

ASTRONOMER, MOUNT WILSON OBSERVATORY; CHAIRMAN OF THE SECTION OF ASTRONOMY.



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DR. CHARLES ZELENY

PROFESSOR OF ZOOLOGY, UNIVERSITY OF ILLINOIS; CHAIRMAN OF THE SECTION OF THE ZOOLOGICAL SCIENCES.



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PRESIDENT OF THE UNIVERSITY OF ARIZONA; CHAIRMAN OF THE SECTION OF THE BOTANICAL SCIENCES.



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PROFESSOR OF PSYCHOLOGY, CLARK UNIVERSITY; CHAIRMAN OF THE SECTION OF PSYCHOLOGY.



DR. WILLIAM F. OGBURN

PROFESSOR OF SOCIOLOGY, UNIVERSITY OF CHICAGO; CHAIRMAN OF THE SECTION OF THE SOCIAL AND ECONOMIC SCIENCES.



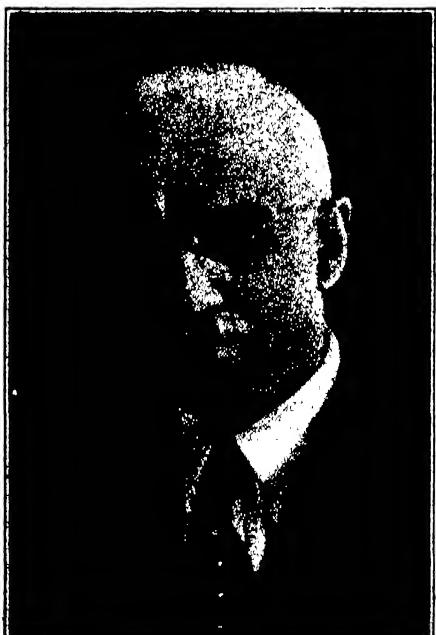
J. H. GOURLEY

PROFESSOR OF HORTICULTURE, OHIO STATE UNIVERSITY; CHAIRMAN OF THE SECTION OF AGRICULTURE.



DR. WALDO G. LELAND

PERMANENT SECRETARY OF THE AMERICAN COUNCIL OF LEARNED SOCIETIES; CHAIRMAN FOR THE HISTORICAL AND PHILOLOGICAL SCIENCES.



PROFESSOR WM. H. PARK

DIRECTOR, HEALTH DEPARTMENT OF THE CITY OF NEW YORK; CHAIRMAN OF THE SECTION OF THE MEDICAL SCIENCES.



DUGALD C. JACKSON

PROFESSOR OF ELECTRICAL ENGINEERING, MASSACHUSETTS INSTITUTE OF TECHNOLOGY; CHAIRMAN OF THE SECTION OF ENGINEERING.

and thus of interest especially to those with a general knowledge of the subject as a whole.

A large number of symposia have been arranged covering a wide range of subjects. The program for Section N (Medical Sciences) will be devoted entirely to symposia. In Section B (Physical Sciences) there will be a symposium on cosmic rays in which Dr. Robert A. Millikan, Dr. Arthur H. Compton, Dr. W. F. G. Swann and others will participate. Another interesting symposium will deal with the late Pleistocene and recent changes of level along the Atlantic coast of North America. Of timely interest is a symposium in Sections K (Economics, Sociology and Statistics) and M (Engineering) on the stabilization of employment, and another on radio problems.

The association has been especially fortunate in having been able to arrange

an unusually representative series of general lectures for the Atlantic City meeting. Eminent speakers will discuss subjects in the fields of anthropology, mathematics, chemistry, physics, botany, zoology, meteorology, astronomy, sociology, dentistry and engineering.

The first general evening lecture will be given by Dr. Franz Boas, the retiring president of the association, who will speak on "Anthropology and Its Aims." This address will be followed by a general reception. Other general lectures will be on "The Social Effects of Mass Production," by Professor Dexter S. Kimball, "The Constitution of the Stars," by Dr. Henry Norris Russell, "Thermodynamics and Relativity," by Dr. Richard C. Tolman, and "Personal Experiences in West Indian Hurricanes," by Dr. Mel T. Cook. And there will be others equally interesting.

AUSTIN H. CLARK



DR. S. A. COURTIS

PROFESSOR OF EDUCATION, UNIVERSITY OF MICHIGAN; CHAIRMAN OF THE SECTION OF EDUCATION.



DR. IRVING LANGMUIR

DR. LANGMUIR, RECIPIENT OF THE NOBEL PRIZE IN CHEMISTRY

IRVING LANGMUIR was born in Brooklyn, New York, on January 31, 1881, and was graduated from Columbia University in 1903 with the degree of metallurgical engineer, after which he spent three years in postgraduate work at the University of Göttingen, taking his Ph.D. degree under Nernst. He returned to the United States in 1906 and became an instructor in chemistry at the Stevens Institute of Technology. Three years later he entered the research laboratory of the General Electric Company in Schenectady, New York, where he is at present associate director, and where his valuable contributions to science and industry have been made. During this time he has received many honorary degrees and other honors from universities and scientific societies, the latest being the Nobel Prize, awarded in chemistry, for the year 1931, by the Swedish Academy of Sciences.

The research of Dr. Langmuir has covered an exceedingly wide range of subjects in physics and chemistry, both theoretical and applied. He is so much at home in both these scientific fields, as well as in their industrial application, that he wanders freely from one to the other, completely ignoring their traditional boundaries, and one is not sure whether his purely scientific work was stimulated by the industrial work with which he has been associated, or whether it has been the purely scientific work that has stimulated his applications of science to industry. The laboratories with which he is associated have given him ample opportunity to follow his genius. Nearly every field in which he has done research has both scientific and practical significance. A partial list of the subjects which he has most thoroughly investigated is as follows: surface phenomena; chemical reactions at very low pressures; the production and properties of atomic hydrogen; the emission of electrons from heated filaments;

valence and the conductivity of electricity in gases. Many of these investigations involved first devising new experimental techniques before the problems themselves could be approached successfully. His outstanding inventions include the gas-filled incandescent lamp, a hydrogen welding torch, a very rapid high vacuum pump, as well as many other improvements in the field of electricity and chemistry.

In 1912 he published his first paper on atomic hydrogen, and with the exception of the discovery by Professor R. W. Wood that atomic hydrogen could be removed from electrical discharge tubes and pumped for considerable distances away from them, almost the whole development of atomic hydrogen has been the result of his pioneer work. His early papers deal with the heat of decomposition of molecular hydrogen into atoms, and, though the value secured was not as exact as values which have been determined since then by more reliable methods, his work was an outstanding accomplishment at the time. The invention of the hydrogen welding torch was the result of correlating the work of Wood with his own observations and gave us an exceedingly high temperature reducing flame for the welding of metals.

His work in the field of surface phenomena appeals to the writer as being the most outstanding development in this field since the classical work of Gibbs. Nearly the whole development in the field of adsorbed films of gases on metallic and other solid surfaces, from the time when Langmuir published his first papers in 1915, has been the result of his thoroughgoing investigation of the subject. He established conclusively that the adsorbed film of substances is monatomic or monomolecular. This he demonstrated very nicely in the case of films of organic substances on liquids, in the case of such things as oxygen and hydrogen adsorbed on metals such as

tungsten and platinum. Recently he has succeeded in laying down a single atomic layer of oxygen on tungsten and a succeeding layer of cesium on top of this oxygen layer. He has devised methods of detecting these films, studying the rate at which they are formed and the rate at which atoms deposited on a surface diffuse over the surface. To appreciate the difficulties encountered in this surface work, one needs to recall that the mass of substance required to form a monomolecular film even over a considerable surface is very small, and much of this work of Langmuir was only possible after devising adequate experimental methods. The theoretical development has been no less outstanding. He has interpreted the experimental data in these fields from the standpoint of two-dimensional gases and liquids and has applied phase rule considerations to them.

Much of the work that Langmuir himself has done, and which is now being done in chemical and physical laboratories the world over was made possible by the invention of a piece of apparatus which now appears to us as being very common and ordinary. High vacua had been secured before Langmuir invented his mercury pump. Some of the pumps known previously up to this time operated upon principles that were at least similar to those used by Langmuir, but the speed of the pump which he devised has been so great that now we secure high vacua in our physical laboratories with the greatest ease.

Two sources of emotional motive power for pure and scientific research are present to a greater or less extent in all scientific workers. They are prompted by an intense curiosity in regard to the way nature behaves and a desire to know the relationships that exist between physical phenomena. This is the attitude of the pure scientist. On the other hand, they also have a desire to see the results of their scientific work made useful to the end of eliminating want, hard labor and the bringing of a

high plane of comfort and luxury to people in general. Langmuir has responded to both of these impulses, and though the Nobel Prize is awarded for pioneer work in pure science, no review of the work of Irving Langmuir would be complete without a mention of his contribution to the applied sciences.

One of his first problems of research after he entered the General Electric laboratories at Schenectady was on the newly invented drawn tungsten filament lamp, which was then of the vacuum type. The glass rapidly became darkened, thus cutting down the illumination, and the filament disintegrated. Langmuir investigated the fundamental causes of these defects and found that they were two in number: first, the tungsten evaporated from the filament, causing disintegration of the filament, and the deposition of a black layer on the inside of the glass surface; and second, traces of water vapor in contact with the hot filament led to disintegration of the filament and a deposition of a black deposit on the glass surface. Langmuir overcame these defects by filling the bulb first with nitrogen gas, which greatly improved the life and brilliancy of the lamp, and later, for special types of lamps, with argon gas. The intensity of illumination from such lamps from the same consumption of power is two or more times as great as it would be without the improvements which he devised.

Another of the recent developments of applied science to which he has contributed in an outstanding way is the thermionic vacuum tube used so extensively in radio. The development of these tubes has been very closely tied up with his work on surface phenomena as applied to the filaments in these tubes, to the conduction of electricity by gases, to which he has contributed in so many ways, and to the securing of adequate and satisfactory vacua for their operation. A large share of the credit for the perfection of these tubes goes to Irving Langmuir.

HAROLD C. UREY

THE SCIENTIFIC MONTHLY

FEBRUARY, 1933

The Scientific Work of the Government of the United States

SCIENCE GUIDES THE DEPARTMENT OF THE INTERIOR

By Secretary RAY LYMAN WILBUR
U. S. DEPARTMENT OF THE INTERIOR

OUR civilization is being made over-right before our eyes under the stimulation of the forces set loose by discovery, research and invention. This new physical world has a firm basis upon undeviating universal laws. It is probably true that we have available a mere fragment of the great structure of knowledge which will eventually be brought into the service of man. Our view-points are rapidly changing. Old assumptions, theories and dogmas are being rapidly pushed out of our minds. In this period of mental ferment, shams have been exposed, the taboos of centuries released, and much has been brought up for discussion which was considered settled by our forefathers.

In the field of government there has been a rapid increase of democracy. To an increasing degree, science has become definitely associated with the development and functions of government. This is the age of democracy and science. Science has no sympathy with substitutes for the truth. Science is giving the human family a unique and unexampled service, and through it the human mind has been vastly increased in its range and mental power.

This is the day of the expert. The man who knows must be recognized and used. In the fields of science the experts can be trained and developed, but such experts require opportunity for long years of study and they need constant exposure to those who are devoting their lives to research; in fact, our progress in our modern civilization is going to depend upon the experimental method rather than upon catchwords, aphorisms or the persistent broadcasting of untried ideas. So close to-day is the link between science and its laboratories and the government that we can measure the progress of a civilization by its economic capacity to support laboratories and by the quality of the intellects brought in to them.

Previous to the depression there had been a fortunate tendency to increase the amount of work done in government laboratories which can be classified as of a fundamental character--that is to say, searching for truth for its own sake rather than for practical procedures immediately applicable to daily life. Essential research depends upon a large amount of reserve time which can be used by men of great curiosity and in-



RAY LYMAN WILBUR
SECRETARY OF THE DEPARTMENT OF THE INTERIOR

dustry without the supervision of others, except in the broadest way. The ordinary administration of government, the ordinary handling of budgets, do not lend themselves well to research. It requires its own technique. In it there will always be an apparent waste of time and false leads. Most leads into the great unknown are apt to end blindly. The discovery of new facts which, once discovered, become the eternal property of man, is full of hazards and uncertainties. In some ways the research worker has as difficult a task as that of a blind man trying to thread a needle. Many attempts must be made before success is assured. Because of this it is most important for the modern democracy to set up its relationships to science from the standpoint of the budget in such a way that funds will not be tagged for specific purposes. Funds should be made available for the securing of the best brains possible and for the facilities that they require, in order to pursue the unknown. While this function is carried on by many independent institutions and as a part of great industrial concerns, nevertheless it seems to me that, since science and government are so closely related, government itself must make liberal grants for investigation and research. In the new world's civilization, which is now a world-wide structure, interlocked economically and with all kinds of interrelations and intercommunications, there is a new conception of world citizenship developed. Truth discovered by the citizen of any country can readily become the property of all. A democracy which is not seeking for new truth and new facts can no longer consider itself safe in this world of harsh reality, where facts determine the issue. These facts, applied either to industry or to national defense, determine not only progress but safety.

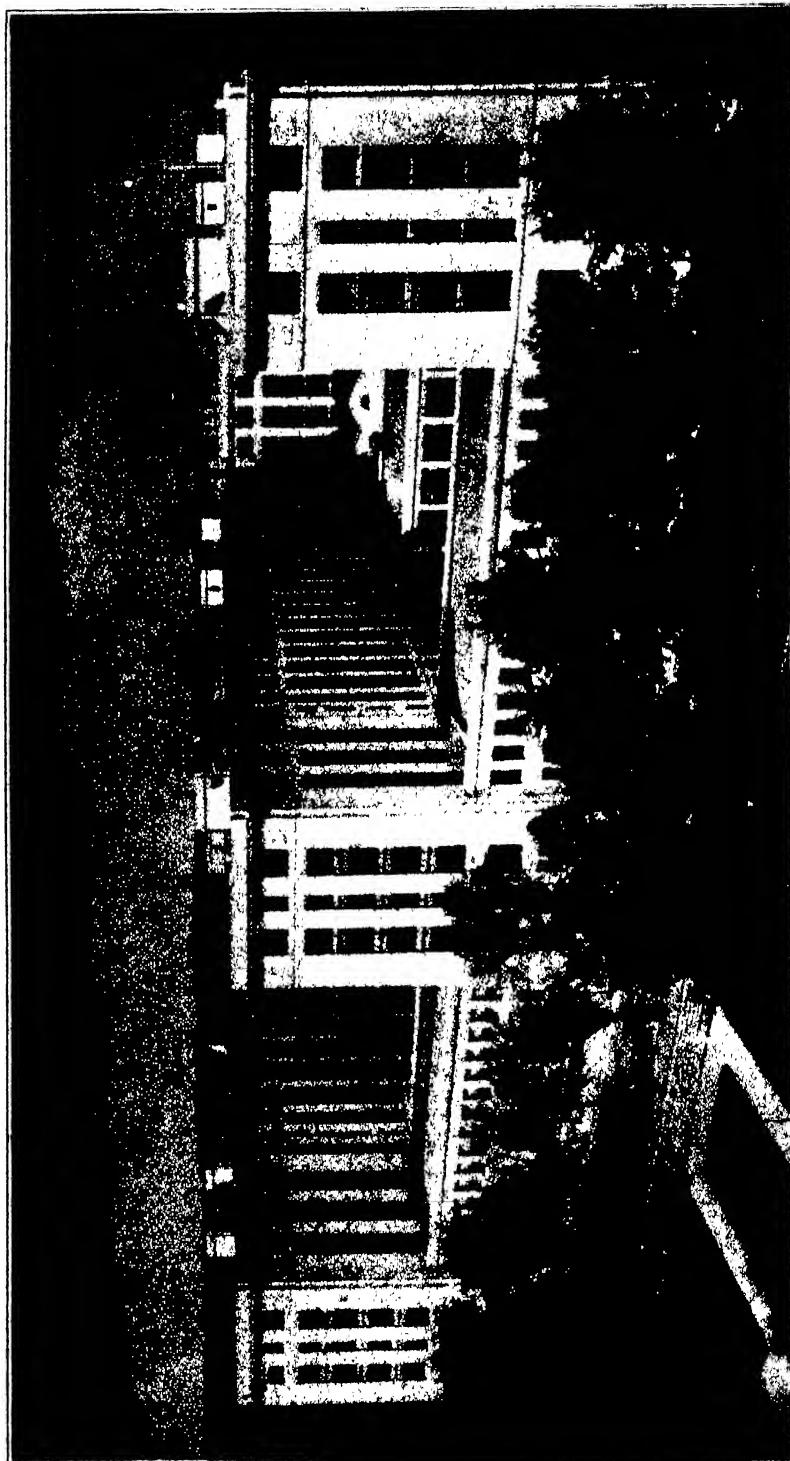
The U. S. Geological Survey is an

example of the service which science can render to government. The geologist with his trained mind has made a study of that part of this great continent which is in our possession. Through years of endeavor and the work of thousands of trained men, we possess a fund of information regarding our mineral, water and soil resources which guides much of our national policy in various fields. It is obvious that without the help of the expert we would have floundered in our conquest of the natural resources of the country. Upon the imaginative mind of the geologist and his capacity to visualize the treasures stored below the surface of the earth depends much of our future national welfare. In the Geological Survey we have had much that was practical but also much that was fundamental.

As a nation we have embarked on a new period of pioneering. Our nation's frontier has dissolved in the Pacific and reappeared in the laboratory and on the school playground. Changes have been necessary to enable this department to do its part in this new pioneering, which means the wisest use of what we have instead of the conquest of new lands, new timber and new minerals. Our people are in the process of adapting themselves to a continent.

A task like that of helping the American aborigine along the path of progress, until he spans in a few generations the gap between the stone and the steel age, calls for the best of scientific thought. Medicine must wrestle with those problems of health that always confront undeveloped peoples in contact with civilization. Education must present itself to the unaccustomed mind. The psychologist must reconcile races that are ages apart. The agriculturist must bring a new training to the reservation.

Aided by all these, the Indian Service



THE BUILDING OF THE UNITED STATES DEPARTMENT OF THE INTERIOR

has turned the corner. Its new goal is to work itself out of a job in twenty-five years. Its new methods center on splitting apart the two separate problems of the Indian's personal welfare and the protection of the Indian's property. These have necessarily been much confused during our nation's hundred years of past wading in the quagmire of Indian administration.

Administering the billion-dollar Indian estate, scattered through many states, has been a job of much clerical detail. The problems of health, education and welfare were allowed to intertwine with this clerical work. As a result, our government's treatment of Indian problems has often been from a bureaucrat's point of view. We have coddled and pauperized one of our finest racial stocks. To-day, as a result of these methods, the average Indian has neither the education, the inclination nor the ability to manage his own property.

The Federal Office of Education comes under the Department of the Interior. The education and training of our children is one of the fundamental functions of our form of government. With us this has been largely in the hands of local communities and of the states. Out of manifold experiences we are developing new points of view and new plans for the future of our American children. The potential possibilities of any child are the most intriguing and stimulating in all creation. Our children will inherit our place on this continent. We must train them to live their lives in the surroundings we have made for them. It is important for us to know how best to instruct our children from the broadest possible standpoints. The White House Conference on Child Health and Protection brought out clearly that we need to do more than to give them food, clothing, training and health protection. We must

lead them to see the basic relations between them and nature and help them to follow the highest ideals and aspirations. The federal relations to the problem of education center in the Office of Education, which has also undergone important changes recently.

It was created as a research organization to gather and disseminate information on educational methods for the benefit of the states. But in the course of time it acquired many administrative functions which should have never been loaded upon it. We have relieved it of these administrative functions. Education of the Alaskan natives was transferred to the Office of Indian Affairs, and other Alaskan responsibilities given to the local government. Consequently, the Office of Education doubled its research activities. A division of special problems was created to study education of exceptional children, of native peoples, of Negroes and of children in sparsely settled regions. A new division of research and investigations was created. A third new division of major surveys was organized to supervise work under special appropriations by outside specialists. These include a nation-wide survey of land-grant colleges, a national survey of secondary education, one on the professional education of teachers, and so on.

The National Park Service does conservation work in a double sense. Wild life of decreasing species is preserved. The big trees in the scenic valleys of California, the geysers and mountains and wild life of the Yellowstone, the peaks and glaciers of Glacier National Park and the wonders of Arizona's Grand Canyon all are rendered available to our people by this bureau's work. But this kind of conservation is but a means to the real objective of the Park Service, which is the recreation and education and health of our people. We are in the midst of the rounding out

of the national park system. Three million Americans each year visit our parks. These parks are the happiest contact points between our people and their government; both gain by it. We are constantly building up its scientific staff. A corps of naturalists are always present to make the lessons of the parks available to the visitor. Geologists and archeologists have become associated with it. Museums are being built up at many points. All the time the national parks are becoming more and more a university of the out-of-doors.

The General Land Office is the agency of this government which has supervised the carving of the public domain into individual homes. Its activities have kept pace with the frontier while settlers overflowed into state after state. The usual action of the Federal Government has been to distribute land resources into private hands as fairly and rapidly as possible. Certain artificial conceptions, such as that of the acre, have been used in dividing up our continent just as we have divided up our cities into town lots of arbitrary size and shape. This has been done largely regardless of the quality of the soil, the amount of vegetation, the water supply, the climate or those other factors upon which all the values of the soil, in so far as the habitation of human beings is concerned, depend.

Unfortunately, Congress has never given the General Land Office or the states adequate authority to protect the public domain from overgrazing and abuse. About 175 million acres remain, most of it valuable principally as a source of water and for grazing. Few of our people realize the destructive effects on the water supply of our valleys which may come from overgrazing and fires in distant mountain country. When vegetation is uprooted by animals or burned by fires, the balance of forces which nature has built up through mil-

lions of years is destroyed. Rains, instead of soaking into vegetation and surface soil, run down barren slopes, wash away the surface, carry it as silt into rivers and fill reservoirs, and form disastrous floods instead of permanent streams. The growing value of the soil is lost, homes are washed away in distant valleys where the smoke of the forest fires is never seen and the grazing animals are encountered only as mutton chops and roast beef.

As to the mineral resources of the nation, this department has a large responsibility. The geologist, the mineralogist, the oil technician, found here a task worthy of his best efforts. Hidden beneath the surface of this land of ours were great stores of coal, oil, natural gas and minerals of many varieties stored there through the ages. In the more thickly settled portions of the country these rapidly came into the possession of private individuals who developed them in accordance with existing economic practices and demands. Fortunately, immense stores were so distant from the market, or so hard to master, that they were left intact, although they were subject to entry as mineral claims. Retaining these for the benefit of the people and permitting their development with a minimum of waste presents problems that only science can meet.

The Bureau of Reclamation has created over a billion dollars of wealth for the nation by its score of reclamation projects throughout the West. There science has turned deserts into prosperous empires in the Salt River Valley in Arizona, and on the Rio Grande, the Colorado, the Columbia and on lesser streams. Reclamation is a wise national policy. It is self-supporting; all construction is financed from a revolving fund which the settlers repay.

To-day we are engaged on the greatest reclamation project of all history.

the building of Hoover Dam on the Colorado River. The problems it presents run the whole gamut of science. Through sale of electric power, already contracted for fifty years, the falling waters of the Colorado will pay for their own capture. A river which is now a threat to hundreds of thousands of acres of farm lands in Arizona and California will be converted into a steady stream of about the volume of the Hudson River at Troy. It will carry commerce, water thousands of acres of arid public lands and furnish drinking water to a dozen cities.

The Territory of Alaska is big enough and rich enough to deserve the fullest possible development. Its resources will still be available for our grandchildren even if used to the utmost now.

The problem of agriculture under the climatic conditions it presents offer a new challenge to science. Its hillsides, rich in minerals, call for new forms of

attack. The fish of its streams, its fur seal colony, its reindeer herds, invite science to new applications of its principles.

In Hawaii, in the mid-Pacific, the department finds contrasting tropical fields to which science may be brought. How well it has succeeded is shown by the fact that large areas to-day are producing unbelievable yields of twelve tons of sugar to the acre and twenty tons of pineapples. Hawaii also presents such a laboratory for the study of race admixtures as has never before been available to any scientific group.

Whether it be the control of trachoma among the Indians, the application of experimental methods in devising means for cooling the great mass of cement in the Hoover Dam or a test of gas pressures in an oil field, science is constantly at work in the operations of the Federal Government in so far as they are placed in the Department of the Interior.



CANYON DE CHILLY, ARIZONA.

THE UNITED STATES GEOLOGICAL SURVEY

By W. C. MENDENHALL

DIRECTOR

ORIGIN

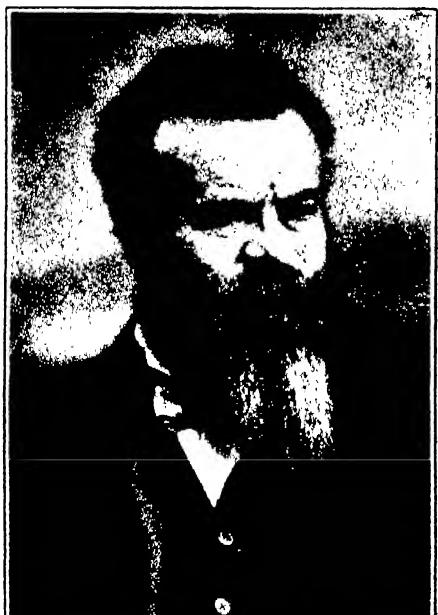
WHILE the U. S. Geological Survey was created by a congressional mandate expressed in the act of March 3, 1879, that mandate was itself a recognition of the development, through the first three quarters of the nineteenth century, of geology as a systematic culture, with widely useful applications in human affairs. Prior to the Civil War several state surveys had been organized, some ephemeral, some permanent. Hitchcock in Massachusetts, the Rogers brothers in Pennsylvania and Virginia, David Dale Owen in Indiana and the Mississippi Valley, Whitney in Michigan and later in California, Safford in Tennessee, Hall in New York, Newberry and Blake in the Southwest, are a few leading names among those associated with official surveys whose work helped to establish the principles and the applications of the science. The Civil War itself checked activities of this sort, but its end released abundant national energies, and the great West then beckoned to the geologic as well as the geographic explorer. Soon Dr. F. V. Hayden resumed his explorations of the upper Missouri Valley, which had begun as early as 1853, but which only after the war developed into the great scientific exploratory organization commonly known as the Hayden Survey. In 1867 Clarence King, who had served his apprenticeship under Whitney in California, organized the Survey of the Fortieth Parallel. In 1869 Lieutenant George M. Wheeler, of the U. S. Army engineers, began his surveys of the Southwest and Major J. W. Powell accomplished his famous exploration of the Grand Canyon, followed in later

years by work in adjoining territory. Powell's work, like Hayden's, was carried out under the auspices of the Department of the Interior; the explorations of King and Wheeler were under the War Department. These four great exploratory surveys brought back striking geographic and geologic results, which attracted wide attention in this country and abroad and led to increasing public support. But the time inevitably came when it was realized that this work under separate organizations, brilliantly conducted though it was, inevitably overlapped in some measure and needed to be coordinated, so that order might be brought out of the growing confusion. Congress in 1878 called upon the National Academy of Sciences to consider the methods of conducting the existing surveys and to recommend a general system designed to obtain the best possible results at the least possible cost. The academy responded in a report approved at a meeting held in New York on November 6, 1878. This report recommended a logical and comprehensive reorganization of the existing agencies engaged in mensuration surveys and in surveys of geologic and economic resources. Its recommendations, however, were carried out only in part. So far as Congress deemed it wise or practicable to adopt them, they were embodied in the organic act of the present Geological Survey, which was established within the Department of the Interior and charged with the examination of the geologic structure, the mineral resources and products of the national domain and the classification of the public lands. The preexisting surveys were at the same time discontinued.



CLARENCE KING
DIRECTOR OF THE SURVEY, 1879-1881.

Clarence King, the brilliant head of the Fortieth Parallel Survey, who had become widely known in scientific circles



JOHN W. POWELL
DIRECTOR OF THE SURVEY, 1881-1894.

through the able reports of his organization and who had attained popular renown through his exposure of the spectacular diamond fraud in southern Wyoming in 1872, was named as the first director of the new organization. King, a friend and intimate of John Hay and Henry Adams, was a man of great versatility and of rare personal charm, but administration, with the peculiar types of burdens and responsibilities that it involves, was not to his liking, so after



CHAS. D. WALCOTT
DIRECTOR OF THE SURVEY, 1894-1907.

launching the new bureau he resigned on March 11, 1881, after less than two years of service. He was succeeded by Major John W. Powell, co-scientist and co-explorer, who, like his predecessor, had prepared for his new work through experience as head of one of the four preexisting organizations.

The roster of employees in the first annual report of the Geological Survey indicates clearly that the leading geologists and geographers who had participated in the earlier surveys were



GEO. OTIS SMITH
DIRECTOR OF THE SURVEY, 1907-1930.

brought into the new organization. Among the geologists appear the names of F. V. Hayden, G. K. Gilbert, S. F. Emmons, Arnold Hague, Raphael Pumpelly and G. F. Becker, and among the geographers Richard Goode, J. H. Renshawe, A. D. Wilson and Gilbert Thompson. W. F. Hillebrand, later to become one of the leading inorganic chemists of the world, was also a member of the group. The new organization was thus born full grown, so to speak, with a staff of trained men, many of them already famous.

Among the earliest questions that confronted Director King was that of the geographic extent of the Survey's field of activities. The organic act defined this field somewhat ambiguously as co-extensive with the national domain. Director King construed "national domain" as essentially the region of the public lands. He recognized, however, that the new organization's value would be seriously limited if its activities were to be confined to a region which, in

the nature of things, must constantly shrink, and his first annual report contains a strong plea to Congress to remove the ambiguity and consequent uncertainty as to the extent of its field of operations. This matter was not finally clarified until 1888, when areal restrictions were removed by making the appropriations of that year available for "geologic surveys in various portions of the United States." This authority has been continued since.

ORGANIZATION

The Survey staff, nearly 80 per cent. of which is technical, includes about 1,000 persons—geologists, engineers, chemists, physicists, editors, librarians, accountants, draftsmen, preparators, clerks, aids of various types, messengers, etc. Its main offices, with library, laboratories and engraving and printing plant, are in the Department of the Interior building at Washington, but it also has 60 field offices distributed over the United States and in Alaska and Hawaii.



W. C. MENDENHALL
DIRECTOR OF THE SURVEY, 1931-

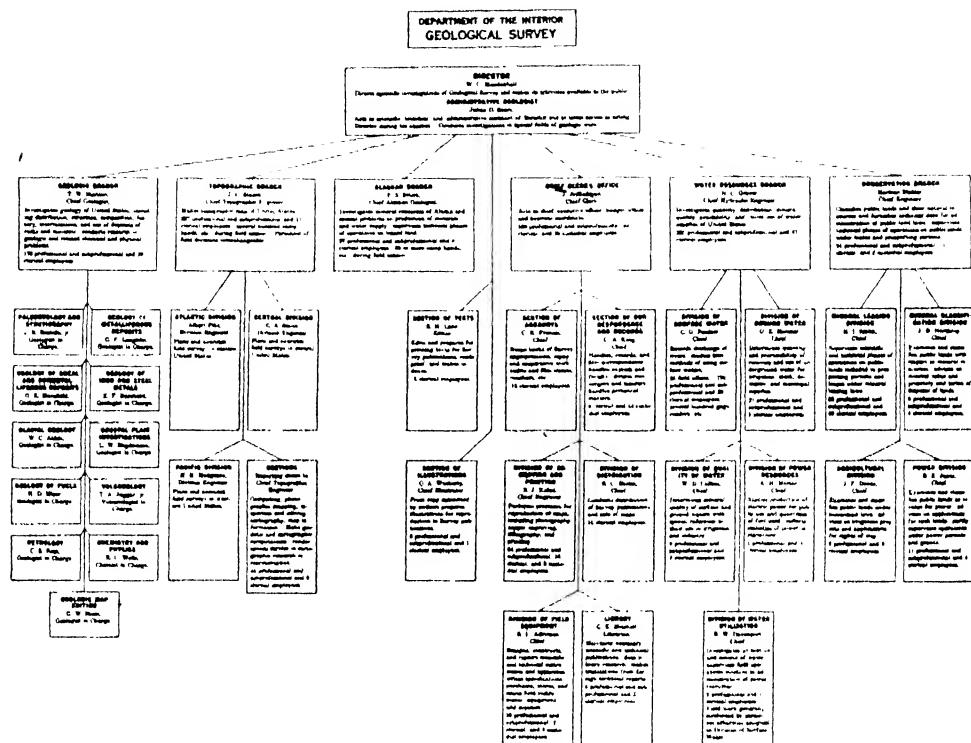


DIAGRAM SHOWING THE ORGANIZATION OF THE GEOLOGICAL SURVEY.

Its investigational work is organized in five great branches—the geologic branch, the Alaskan branch, the topographic branch, the water-resources branch and the conservation branch. Of these all are functional except the Alaskan branch, which is geographic and includes all the activities of the Survey in Alaska. Each branch contains several divisions and sections through which the work is administered in detail.

The subsidiary services—including the engraving and printing plant, in which are engraved and printed all folios and topographic maps, many geologic maps in addition to the folios and miscellaneous maps for other government establishments; the library of 200,000 or more books and pamphlets, mainly geologic; the editorial group; the accounting and distribution sections, and the instrument shop—are administered through the director's office.

The accompanying diagram, though so reduced as to be scarcely legible, indicates the general organization.

The Survey has published about 2,000 volumes of reports, thousands of geologic maps and millions of copies of topographic maps, nearly 1,500,000 of the topographic maps having come from the presses in 1932 alone.

GEOLOGIC WORK

From the beginning of its history, although other functions have been given to it by law, either directly or by implication, the Survey has regarded geology as its primary field. Geology, of course, like the other general sciences, is now a complex group of fields of knowledge, not a single field, and geologic investigations are staff investigations rather than those of an individual. Moreover, geology has many interrelations with the sister sciences of physics, chemistry, as-

tronomy and biology. Paleontology in its various branches; general evolution, as it may be studied and interpreted through the remains of extinct life, vegetable or animal; sedimentation, its processes and products; mineralogy; petrography as an aid in the study of igneous and altered rocks particularly; metallic ores, the conditions of their deposition and their distribution; non-metalliferous deposits of economic value; the evolution of the earth's crust, the structural features that affect it, the surface forms that are impressed upon it, and the agencies that have produced these forms; volcanology; chemistry and physics as they are involved in studies of rocks—all these and others fall within the fields covered by geology, and all of them have received some measure of the energies available to the Survey since its establishment. Its founders, although they inherited the experience and much of the personnel of the earlier national surveys and had access to the knowledge acquired through the activities of the preexisting state organizations, nevertheless had to establish principles to guide the conduct of the new organiza-



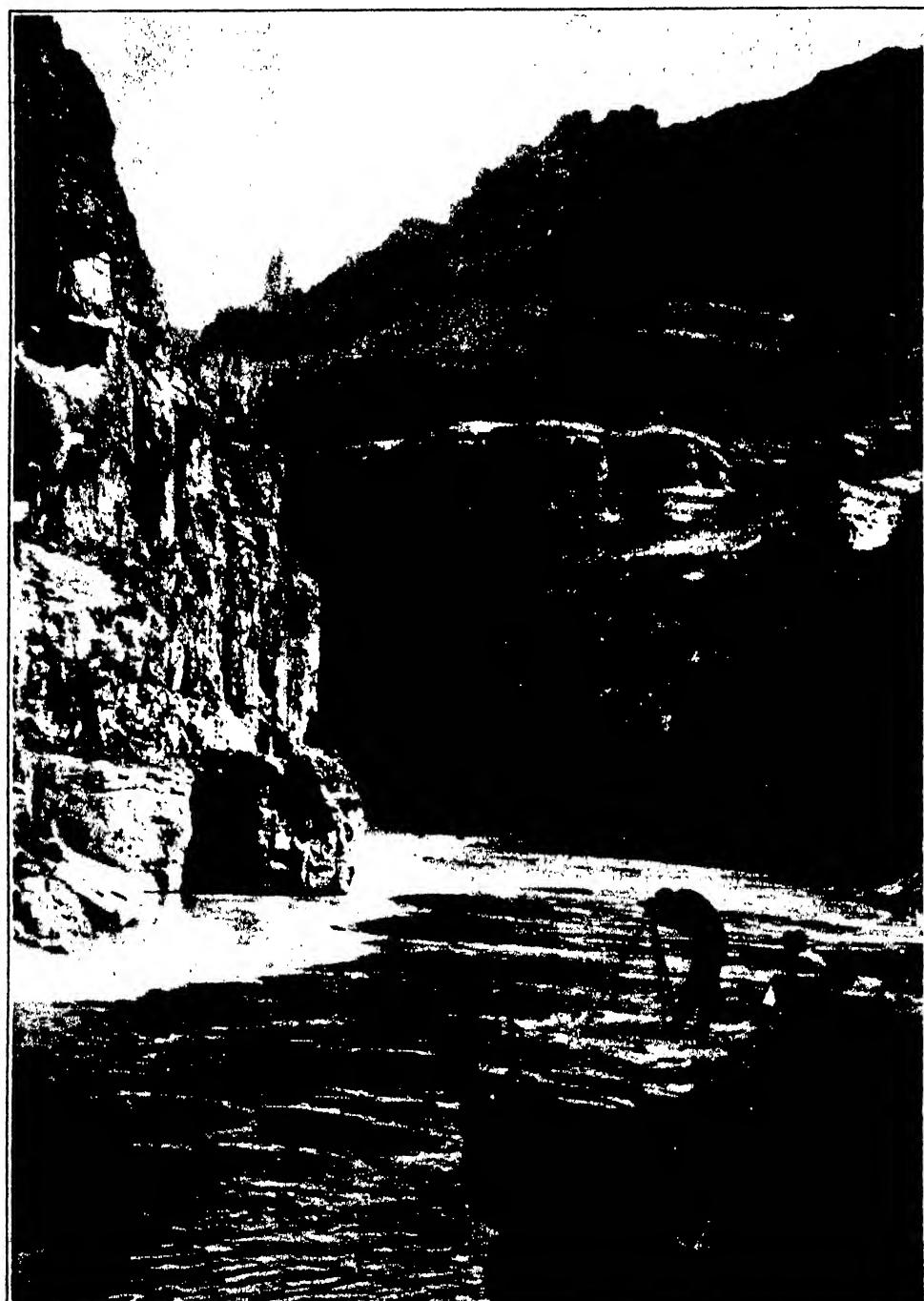
GAGING A STREAM BY WADING.

tion and to adapt or evolve systematic methods by which its work could be accomplished. Simple areal mapping, one of the most valuable means of revealing critical geologic relations, itself required decisions as to scales to be used, degree of refinement of the work, definition of units, and methods of field work that would yield clear and consistent final products.

The mineral deposits, particularly of the then new West, were among the things of economic importance with which the new organization was expected to deal helpfully, from the beginning. In order that it might aid the mining industry in a practical way, intensive and thorough studies were essential, to decipher the laws governing those particular types of earth chemistry and rock alteration which result in ore deposits. The studies at Leadville and on the Comstock Lode were pioneer investigations to this end, involving co-operation by geologists, chemists and physicists. They greatly increased the understanding of the complex laws of ore deposition and association.



MEASURING THE FLOW OF A STREAM
BY MEANS OF CABLE AND CAR.



TOPOGRAPHIC PARTY AT WORK BELOW BOULDER RAPIDS IN MARBLE CANYON
OF COLORADO RIVER.

In the field of ores of the metals intensive studies of known deposits have resulted in a better understanding of conditions of ore occurrence, which has greatly extended the productive life of the districts studied, as at Leadville. Even more important, however, is the fact that the accumulation of such data has led to broad and highly practical generalizations on ore occurrence. Such concepts are the theory of enrichment, the theory of zonal distribution of primary ore deposits, and the relation of ore deposits to apically truncated stocks. The application of these principles and others by the mining industry has resulted in greatly increasing the probabilities of success in the exploitation of metal deposits and has prevented expensive exploration of many unprofitable deposits.

At present studies that promise to be equally fruitful are being directed toward the relations between ore occurrence and the geologic structure of the surrounding region. Metamorphism, mild or intense, has practically always accompanied deposition of the metals, and further systematic study of the results of this process is likely to give significant clues to the positions and relations of ore bodies.

The prospecting of the future must be guided by geology. The old easy days, when in an undeveloped mining country the prospector, working at the surface with his pick, could uncover bonanzas, are gone. The rich deposits to be found hereafter lie not at the surface, but deeply buried, and must be discovered, if at all, by the application of geologic principles.

The ultimate value of any science lies, of course, in its applicability to human needs and human advancement. But the inherent nature of research—a systematic endeavor to learn the unknown, to extend man's knowledge of the substances and forces of nature—is such that progress in it must be slow. What

mankind in the mass is mainly interested in is the application of science; what too few realize is the long period of patient labor involved in the establishment of guiding principles or the finding of new products.

A quarter of a century or more ago the Geological Survey began a systematic search for usable deposits of the fertilizer mineral potash in the United States. None of any importance in this country were then known. Slowly, as energy and funds could be made available, all promising regions within our borders were examined. The great salt deposits of New York, Ohio, Michigan and Kansas were investigated. All the Western playas were systematically studied and tested. Failure after failure resulted: one locality after another was discarded. Eventually, in part as a result of the Survey search and in part as the result of the activities of industry, two Western localities were developed—Searles Lake, in California, and the Salduro Basin, in the western part of the Great Salt Lake depression. But it was hoped that more extensive bedded deposits, similar to those of Europe, might be found, and the search continued. After other localities had been eliminated, it still seemed possible that commercial bodies of potash might exist in the great Permian salt basin that extends northeastward from western Texas and eastern New Mexico into Oklahoma and Kansas. Attention was concentrated on this basin. Studies were made of cuttings from wildecat oil wells that were being drilled here and there in the basin, and polyhalite, a low-grade potash mineral, was found in many of these cuttings. The search was intensified in the hope that richer salts might be found. Eventually drillers of a wildecat oil well in eastern New Mexico, on the alert because of Survey stimulation, found sylvite. Cores were taken, and sylvite and other rich minerals were found in beds sufficiently thick to be



VIEW OF THE AJO COPPER MINE IN ARIZONA, WHICH IS BEING STUDIED BY THE GEOLOGICAL SURVEY.

mined. There now exists, near Carlsbad, New Mexico, a successful potash mine which has already produced nearly 100,000 tons of salts running 25 per cent. or more of K₂O. Other mines are in course of development. This result is the culmination of a long series of patiently conducted studies with an economic objective.

Early in the exploration for crude petroleum, the anticlinal theory was evolved by I. C. White. Modified and developed from its original form, it has been an important instrument in the search for crude petroleum for more than half a century, and its use has tremendously simplified that search and increased the chances for success. A later and only less important generalization is David White's carbon ratio theory, which eliminates great areas in which millions of dollars might have been wastefully expended. Investigations are now being made as to the source materials of petroleum. Scientific men can not predict the outcome of their studies: if they knew the outcome, the studies would be unnecessary. Hence no claim can be made about the results that may accrue from this study, but it may easily be possible that, as the anticlinal theory aided in the concentration of the search in the more favorable areas and as the carbon ratio theory added further limitations and thus gave new guides to explorations for oil, so the studies of source rocks may furnish to

those engaged in the search for new pools an additional factor of control.

TOPOGRAPHIC MAPPING

It was realized from the beginning that geologic mapping could not be accomplished without base maps on which to record geologic units in their proper relations. So the Survey has always made topographic maps. It inherited the art of map-making in its earlier and crude form from the preceding organizations, but it has developed this art until the modern topographic maps are not only rigidly controlled as to position and adapted in scale to the various uses for which they are designed, but are both accurate and graphic in their delineation of land forms in all their infinite variety. They now find manifold uses other than their original use as base maps for geologists and are in wide demand everywhere, but less than half of the United States is yet covered by these maps.

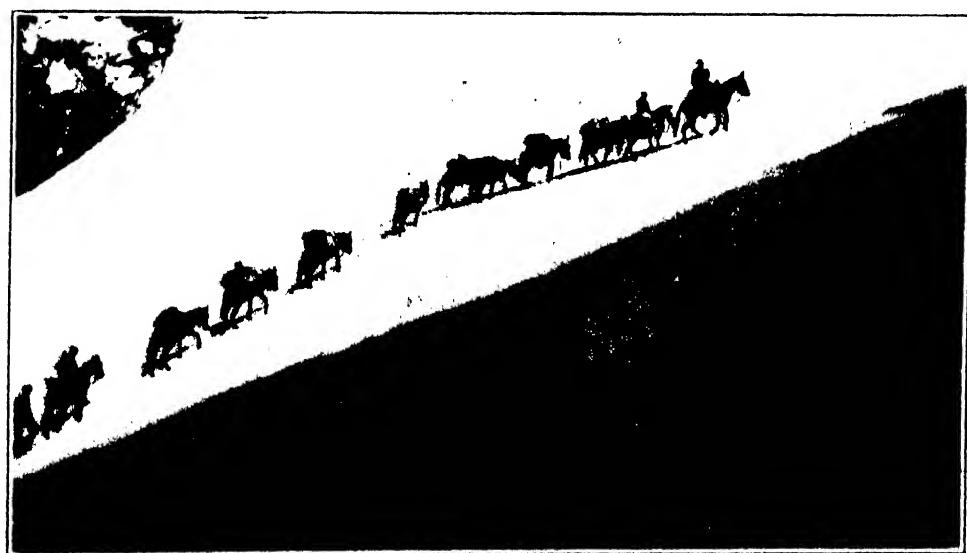
WATER RESOURCES

Major Powell was a broad philosophic naturalist rather than a specialist in the field of geology. His years of exploration in the West had stimulated in his eager mind an intense interest in all the problems of the frontier. Among these problems none appealed to him as of more importance than development of the arid and semiarid regions by irrigation. In the 70's and 80's of the last

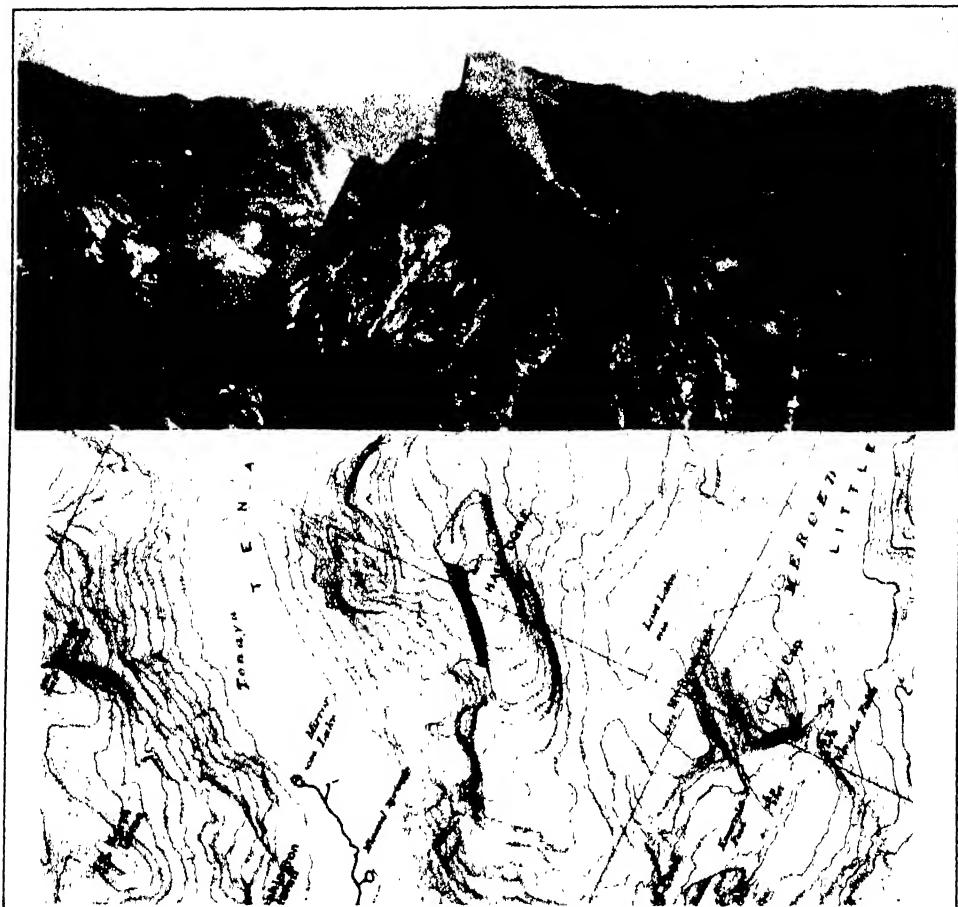
century it was far clearer to him than to most of his contemporaries that agriculture in the regions of meager rainfall would be restricted to but a fraction of the total acreage by the limitations in the water supply, and that if opportunities for irrigation and reclamation were to be realized, reservoir sites and dam sites must be preserved and accurate information must be obtained about the quantity of water available. His activities resulted in the designation and withdrawal from entry of large areas in the West in the late 80's for irrigation development and in the beginning of systematic studies of stream flow. In recommending these withdrawals, as in many other respects, Major Powell was a generation ahead of his time. His action was bitterly attacked, and most of the areas withdrawn were restored to entry, but the principles that were to be followed in the future had been established and the groundwork laid for later systematic determination of available water supplies. Thus the work of stream gaging was initiated. It has been continued to the present time, and

out of it and the early irrigation studies grew in 1902 the reclamation act and later the establishment of the Reclamation Service as an independent bureau.

As the East has become more densely settled, water consciousness has traveled from the arid regions eastward across the continent. Our great cities are now confronted with problems of water supply scarcely less acute than those that confronted the early settlers in Utah or along the meager streams or springs of the arid Southwest. These cities must foresee their needs decades or generations ahead and provide for those needs by acquiring sources of water for their constantly growing populations. So the necessity for accurately determining stream flow and for protecting streams from contamination by industrial wastes or through human occupancy is now recognized in the East as well as in the West. The development of hydroelectric power, to be efficiently planned, also requires knowledge of the available stream flow obtainable only through long-continued observations. Studies of underground water resources, on which many



PACK TRAIN OF A TOPOGRAPHIC PARTY SURVEYING MT. GODDARD
QUADRANGLE, CALIFORNIA (1907)



YOSEMITE VALLEY, CALIFORNIA, WITH TOPOGRAPHIC MAP OF IDENTICAL AREA. (HALF DOME IN CENTER)

of the smaller cities and towns, as well as most of the Eastern farms, depend for their supplies, are likewise essential to wise planning. The natural initial tendency is to regard such resources as unlimited in quantity, and it is only when these supplies begin to diminish through overdrafts or become contaminated that the necessity for systematic studies of their limitations and quality is realized. This work too has grown as one of the functions of the Survey and now is practically coextensive with the domain of the United States.

ALASKA

After its purchase from Russia in 1867 Alaska was neglected for thirty

years. A few traders, trappers and prospectors followed its rivers and penetrated its fastnesses, but generally it remained unknown--a forgotten land. The energies of our people were absorbed in subduing their mainland frontiers. A few private and government exploratory expeditions, which brought out trustworthy records and thus contributed to our knowledge of Alaska's geography and natural history, had been made prior to 1898. The names of Dall, Stoney, Allen, Schwatka, Hayes and Spurr are associated with extensive and heroic explorations of great value. After the gold discoveries in the Canadian Klond-

dike in 1897 came the great gold rush of 1898 and a stimulation of government interest in its northern territory. Hayes in 1891 and Spurr, Schrader and Goodrich in 1896 had represented the Survey in the earlier explorations, but beginning with 1898 the Survey has carried on continuous and systematic work that has now covered about 45 per cent. of the 600,000 square miles included in the territory. Topographic maps and reports on the geology and mineral resources, with incidental information on climate, vegetation and conditions that confront the traveler, are available for all areas where Survey geologists and topographers have been. The broad outlines of the geology and geography of much of this great northwestern salient of the continent are known, and some of the more critical points have been studied in detail.

Much of the work has been done under severe conditions, scarcely hinted at in the laconic and objective reports. The code of the scientific explorer precludes dwelling upon personal hardships and difficulties, which are regarded as all in the day's work, and professional self-respect leads him to foresee, to plan wisely and to execute efficiently, thus avoiding failures and disasters. Hence the record of more than one third of a century of Survey exploration in this remote region is unmarred by a single fatality. On the other hand, it has yielded volumes of reliable information and adequate maps of thousands of square miles for the guidance of those who may follow the survey explorers.

CONSERVATION ACTIVITIES

Classification of the public lands is one of the duties placed upon the Survey by its organic act. Specific classification as a basis for the administration of the public land laws, however, was not provided for fiscally in the early years of the Survey's existence. This function, therefore, remained dormant

until it was vivified under President Theodore Roosevelt early in the present century. Under a policy that he inaugurated and that has been continued since, public lands believed to be valuable for their content of coal, oil or certain other minerals were withdrawn from entry until they could be definitely classified and made available for acquisition under appropriate laws. This practice was later extended to lands valuable as public watering places and stock driveways or for the development of irrigation and water power, and it is now established as a recognized part of public land procedure. During the last twenty-five years Congress has enacted other measures, such as the enlarged and stock-raising homestead laws, that require specific classification as an essential feature in their administration. To meet these responsibilities it has been necessary for the Survey to organize a staff of geologists, engineers and other specialists for the purpose of separating the public lands into the categories recognized in the statutes.

The technical phases of the administration of the various mineral land leasing laws have likewise devolved upon the Survey since 1925. Prior to that time this work had been a part of the duty of the Bureau of Mines, but with the transfer of that bureau from the Department of the Interior to the Department of Commerce on July 1, 1925, the engineering features of the administration of leases of mineral deposits in public lands became one of the Survey's responsibilities. In performing this function, as in that of classifying the public land, it must work in close cooperation with the General Land Office, the office of record and of initial consideration of legal questions involving public lands. The work is built within the framework of general policies controlling all public land matters as expressed by Congress in legislation and



MT. WRANGEL, ALASKA, AN ACTIVE VOLCANO, 14,000 FEET HIGH.

by the Secretary of the Interior in administration.

COOPERATION

In a communication to a state geologist the first director of the U. S. Geological Survey said: "The director desires to announce to you that he urges the inauguration and continuance of state surveys and wishes to cooperate with them to the mutual advantage of both." Thus one of the basic policies of the Federal Survey was announced in 1880. That policy guides its relations with other scientific organizations to-day as it did 53 years ago. Support of state surveys and cooperation with them to the end that there may be co-ordination in purpose and in results achieved is one of the guiding principles of the federal organization. It realizes that the problems awaiting solution in the field of geology and in other fields occupied by the Federal Survey are almost unlimited and that all the energies—state, local and national—that can be marshaled for their solution and for

the services that can be rendered to mankind through research in these fields will be totally insufficient to accomplish the progress that should be made. In 1884 an agreement was made between the Geological Survey and the Commonwealth of Massachusetts for cooperation in the preparation of topographic maps of that state, the costs to be shared equally between the state and the Federal Government. Many such agreements, involving topographic mapping, investigations in many of the fields of geology and the study of water resources, have since been executed. Within the past decade particularly, this method of financing work that both the individual commonwealths and the Federal Government desire to have done has been used extensively and has become a definite policy recognized by Congress in the annual appropriation acts. Approximately a million dollars has been expended during each of the past two years by states and municipalities to the end that high-grade topographic mapping might be expe-

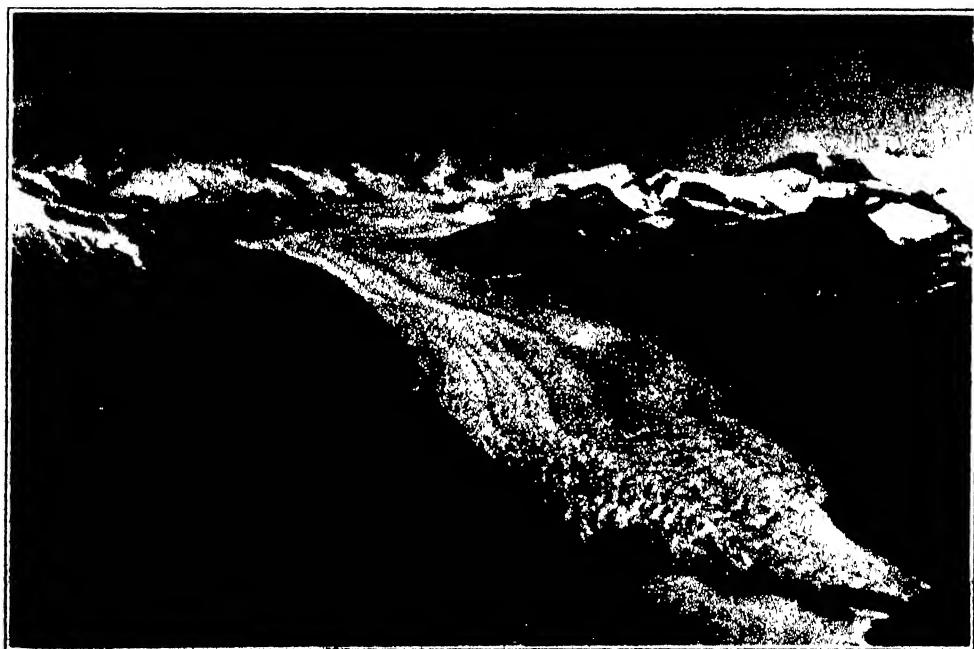
dited and vital studies of water supplies carried on within their borders through the agency of the Geological Survey.

MOTHER OF BUREAUS

With the growth of the nation and the increase in complexity of the problems of government, the Survey, through its own initiative or because it has been called upon by Congress or the Administration, has engaged in activities some of which either have not been definitely related to its main purposes or have attained a magnitude worthy of separate recognition. As the value of certain of these activities has come to be recognized, they have been separated from the Survey and delegated to independent organizations. The first of these activities thus to be set apart was that of the study of the cultures of the North American Indians, a study initiated by Major Powell prior to the creation of the U. S. Geological Survey. Throughout his directorship Major Powell maintained a

deep interest in this field and created a small organization through which studies of the ethnology of the North American Indians were carried on. Eventually a bureau was established within the Smithsonian Institution for the continuation of this work. Upon his retirement from the directorship of the Survey, on July 1, 1894, Major Powell assumed the directorship of the Bureau of American Ethnology, which he held until his death in 1902.

From the time of its creation the Geological Survey, as an incident to its regular topographic and geologic surveys, had assembled facts on the distribution and character of the timber resources of the West. As a result of this early activity the Survey was called upon, after the enactment in 1891 of the law authorizing the President to set aside forest reserves on public lands, to advise the Secretary of the Interior about areas that might appropriately be thus reserved. In 1897 an appropriation was made for the survey of lands



DAWES GLACIER IN SOUTHEASTERN ALASKA.

then in forest reserves or contemplated for designation as forest reserves, and it was specified that these surveys should be made by the Geological Survey. This work was continued for several years and resulted in a series of reports on forest lands, with maps indicating their appropriate classification. The data thus collected served as a basis for regulations for the administration of these lands, although the administration itself at that time rested in the General Land Office. By 1905 forest reserves were recognized as of sufficient public importance to require the creation of a definite unit of government for their administrative control. Work which prior to that time had been done in both the Departments of the Interior and of Agriculture was combined and transferred to the Forest Service under the Department of Agriculture. Thus the early work of the Survey had much to do with laying the foundations for that efficient unit of government.

Interest in the possibilities of irrigation of the arid lands of the West had, of course, existed since the West became known. Congressional interest had been most definitely indicated by the act of 1888, already mentioned, which provided that lands valuable as reservoir sites and dam sites should be withheld from entry, but the public objection to excluding these large tracts from acquisition at that time retarded the movement for federal irrigation for a decade or more. Nevertheless, the interest then aroused continued, one of its manifestations being the first specific appropriation of \$12,500 for the gaging of streams and determination of water supplies, made in 1894. This work, so essential to the effective planning of any irrigation project, was continued and expanded, and finally in 1902 the reclamation act was passed. This act provided for government construction of irrigation works, the costs to be gradu-

ally repaid by the owners of the irrigated lands. The reclamation act thus grew out of the earlier studies of the Geological Survey, and its administration was at first intrusted to Director Charles D. Walcott, of the Survey, and remained under his guidance until 1907. In that year, upon his urgent recommendation, the Reclamation Service (now called the Bureau of Reclamation) was created as a separate bureau in the Department of the Interior.

An extensive correspondence, which has never been published, was carried on between Clarence King, the first director of the Survey, and Dr. Carl Barus, one of the most distinguished among American physicists at that time, about the possibility of locating ore bodies underground by measuring electrical conductivity between two or more distant points. Indeed, an unsuccessful experiment was actually made in the field in an endeavor to make use of this method of ore finding. Interest of the early geologists of the staff in the possibility of combining physical and geological methods was not, however, abated because of the failure of this first experiment. It became clear to these thinkers that a long, slow series of investigations in the general field of geophysics must be carried out before successful practical applications could be expected. Minor beginnings were made in such work, but all these studies were abandoned in 1892 with the severe decreases effected that year in funds available for the Survey's work. Eight or ten years later it became possible to give further consideration to the general problem, and from 1900 to 1906 a moderate amount of research on this subject was carried out in the Survey laboratories. The experiments had become sufficiently promising by 1904 to induce the Carnegie Institution of Washington to aid the research with a grant of money, and by 1906 the work was placed upon a permanent basis by the Carnegie In-

stitution through the establishment of its Geophysical Laboratory, to which the work theretofore carried on by the Geological Survey was transferred. The highly important scientific results attained in this laboratory during the past quarter of a century are, of course, to be attributed to its able director and admirable staff, yet the Geological Survey had no small part in its beginnings.

It was inevitable that the work done by the Survey in the mining regions of the West should bring it into close contact and sympathy with mining problems *per se*--that is, the problems of the mining engineer in the recovery and treatment of ores. The Survey's own logical field is not that of recovery or treatment of ores but that of ore bodies as geologic units--their occurrence, their geologic environment, the reasons for their existence and the possibilities of the existence of other bodies and their probable locations. Mining men, however, have repeatedly expressed the desire that the Survey expand its work beyond that of the geology of the ores to include the problems of recovery. In response to this need there grew up within the organization, at the beginning of this century, a technologic branch, which dealt more specifically with the problems of the mining engineers. This branch proved its usefulness to the mining industry and eventually was recognized as of bureau status and separated in 1910 as the Bureau of Mines.

The Survey takes much pride in these vigorous and useful organizations that have grown out of its own earlier activities, and it also takes pride in the fact that, throughout its career, it has adhered so far as possible to its own main lines of endeavor. As the activities extraneous to these main lines have developed and proved their usefulness, it has welcomed their recognition as additional units of government.

FUNDS

Scientific readers need not be told that the very nature of scientific work is such that continuity and certainty of such financial support as is extended is essential. The certainty of support is almost more important than its magnitude. The studies that promise greatest value should not only be carefully planned but continuously supported to completion. The universities and the foundations, in this respect, have a distinct advantage over publicly supported research groups. Legislative bodies, state or national, however sympathetic they may be with long-continued studies of the research type, find difficulty during periods of economic stress in providing funds for work that does not have an obvious, immediate and direct bearing upon a state or national need. During periods when treasuries are well filled the desire which prevails among many of these bodies to support research as a proper part of governmental activity can be realized without great difficulty, but in times of fiscal depression, when there is an almost irresistible public demand for the reduction of so-called "non-essential" public activities, it quite naturally appears to them that the research type of work can be deferred. It is by no means always appreciated that to carry such work forward fruitfully requires long, slow and careful selection of well-trained staffs, and that as these staffs gain experience their value and the likelihood that they will make contributions that will ultimately result in great national benefit increase with the passage of time. The dispersal of such staffs and the consequent interruption or abandonment of the projects on which they are engaged results in irreplaceable loss, so that fluctuations in funds from year to year, now up and now down, create a fiscal environment that is most inimical to valuable research.

The Survey, like all scientific organizations supported by appropriations, is affected by these adverse conditions. Perhaps the surprising thing is that it has not been even more seriously affected. Nevertheless, there have been periods in its history, of which the present may prove to be one, that have been very adverse to orderly scientific work.

The appropriation available to the Survey for the first year of its existence, namely, the fiscal year 1880, was \$106,000. This amount was slowly increased during the next decade until it reached \$879,000 in 1890. Then began a period of decline, culminating in 1893 and 1894, when appropriations of \$488,000 and \$495,000, respectively, were made for its activities, which by that time had become rather complex. Another period of slow growth then began until in 1909 the appropriations available to the Survey amounted to \$1,800,000. This was followed by another decline to less than \$1,500,000 during 1912 and 1913. Although during the world war a large portion of the Survey's energies were absorbed directly and indirectly in special war services, it did not participate in the appropriation increases that were so general during that period, and after the war, in 1919, its total appropriations aggregated slightly less than \$1,438,000. The sums available during the next few years fluctuated in general

only by the amounts added to enable the Survey to discharge additional duties thrown upon it. The chief of these additional duties was the administration of the mineral leasing laws transferred to it from the Bureau of Mines in July, 1925. Moreover, a policy of Congress which began to be effective toward the end of the decade 1920-30—the policy of meeting on an equal basis the co-operation offered by states and municipalities—required increases in the federal funds for topographic mapping and investigations of water resources. These factors, together with moderate additions to funds for research work and for publication, eventually brought the appropriations to their high-water mark of \$3,141,000 in the fiscal year 1932. Since then the great drop in federal revenues and the response of Congress to this drop through its reduction in federal expenditures brought the funds available to the Survey in 1933 down to \$2,615,000, and the act as passed by the present House proposes to reduce the amount available for 1934 to \$1,927,500. The most regrettable feature of these decreases is the fact that they fall so heavily upon the Survey's basic research work and upon the publication funds, through the use of which the products of its activities become available to the public, to educational institutions and to industry.

THE OFFICE OF EDUCATION

By Dr. WM. JOHN COOPER

U. S. COMMISSIONER OF EDUCATION

THE Constitution of the United States makes no mention of education. How, then, does it happen that we have an Office of Education in the Department of the Interior? This question troubles many people, especially those who are fearful lest there be set up in this country a department of education similar to those which function in some European countries. As a matter of fact, the Constitutional Convention did discuss the inclusion of education among the powers given to the Federal Government, but reached the conclusion that, though very important, education was a subject which each state could handle in its own way.

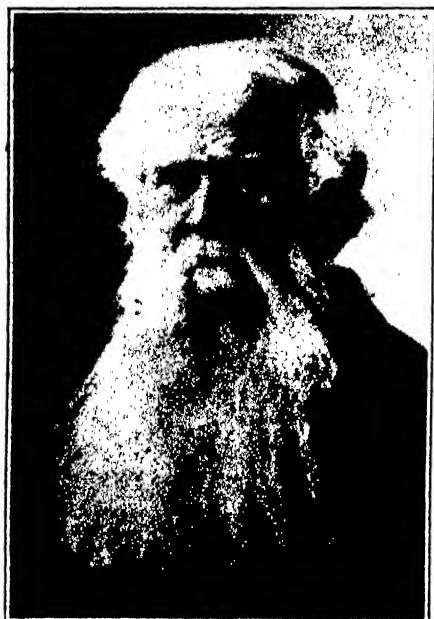
Federal interest in education may be said to date from the census of 1840, which was the first census to gather any figures on illiteracy in the United States. This action was due to the vision of Henry Barnard, secretary of the board of education of Connecticut. Dr. Barnard had traveled around over the country, lecturing in various states, and he realized how little we knew about the systems of education which had developed in the different states.

Therefore, in 1838 he came to Washington and conferred with various members of the Secretary of State's office, which, at that time, had charge of the census. Eventually he reached Mr. Hunter, who had the preparation of the schedules of the 1840 census in hand. He induced him to incorporate into the inquiry form certain questions which would show the condition of literacy in this country. By order of Congress the results of this inquiry were sent in manuscript to Dr. Barnard as soon as tabulated, and in 1841, on the basis of

these returns, he prepared an address on "The Magnitude of the Educational Interests of the United States and the Necessity of Great and Immediate Improvement in State and City Systems of Public Instruction." This address aroused Horace Mann and other leading educators of the time to emphasize the need for more public schools. From this time on to 1867, Barnard himself consistently urged a department of education in the Federal Government.

In 1845 and again in 1847 Barnard endeavored to get "the diffusion of a knowledge of the science and art of education, and the organization and administration of systems of public schools into the plan of the Smithsonian Institution." On October 17, 1849, a convention met in response to a call for "a national convention of the friends of common schools," signed by Bishop Alonzo Potter, of Pennsylvania, Horace Mann, Henry Barnard, and others. At this meeting the following resolutions were adopted: "*Resolved*, That a committee of five be appointed to prepare a memorial to Congress, asking the establishment of a bureau in the home department for obtaining and publishing annually statistics in regard to public education in the United States." At a meeting of the officers of the American Institute of Instruction held at Lynn, Massachusetts, on January 4, 1851, a committee was appointed "to consider the expediency of petitioning Congress with reference to the establishment of an educational department at Washington."

At the fourth meeting of the American Association for the Advancement of Education, held in Washington, Decem-



HENRY BARNARD
COMMISSIONER OF EDUCATION, 1867-1870.

ber 26, 1854, a resolution was passed approving the distribution of lands for the support of education. In addition to this, it was asserted that "it entertains the strongest convictions that the interests of public education will be greatly advanced by the establishment in connection with one of the departments of government of a depository for the collection and exchange of works on education and the various instrumentalities of instruction."

Commenting upon the reorganization of educational associations which occurred with the formation of the National Teachers Association in 1856, Dr. Mayo said, in reference to the American Association for the Advancement of Education, "All proceedings of this body of educators, which only dissolved on the organization of the National Teachers Association in 1856-58, had but one logical tendency—that in some way the National Government should interest itself again in the education of the whole people."

At the meeting of the National Teachers Association in Cincinnati, on August 11, 1858, President Z. Richards delivered an address in which he said in part: "The subject of a national bureau of education, to be connected with the Department of the Interior at Washington, has often been spoken of, and urged, as worthy of Congressional legislation. . . . We believe, however, in common with some of the wisest and most considerate friends of education, that a special effort should be made to establish at our national metropolis a *central and national educational agency*, by the aid of which more efficiency and uniformity of character may be secured in the educational movements of our country; and a library of educational books and publications collected from every part of our country and the world."

The following year Mr. Valentine moved a resolution: "*Resolved*, That a committee of three be appointed to confer with the Honorable, the Secretary of



JOHN EATON
COMMISSIONER OF EDUCATION, 1870-1886.

the Interior, to ascertain what additional statistics in relation to the subject of education are desirable and feasible to obtain by means of the approaching national census." In 1860, this same association, meeting in Buffalo, from August 8 to 10, was advised in the introductory address of President J. W. Bulkley that Congress be urged to inaugurate a department of public instruction. "With such a department," he said, "having the necessary appliances, and an intelligent and efficient head, we can hardly estimate its power and influence."

The Civil War interrupted for a time agitation along this line, but when the National Teachers Association met at Ogdensburg, New York, from August 10 to 12, 1864, Professor S. H. White read a paper on "A National Bureau of Education" and offered a resolution which read: "*Resolved*, That in the opinion of this association, the educational interests of the country would be greatly advanced by the establishment of a national bureau of education." A committee of three was appointed to attend to the details.

The next year, at a meeting held at Harrisburg, Pennsylvania, Professor Rickoff declared "that Congress, at the very next session, should establish an educational department, and authorize the President to appoint a Commissioner of Education."

In February, 1866, the National Association of State and City School Superintendents met in Washington, D. C., and urged the creation of a national bureau of education. They appointed a commission, consisting of Dr. E. E. White, state commissioner of common schools of Ohio, Newton Bateman, superintendent of public instruction of Illinois, and J. S. Adams, secretary of the state board of education of Vermont, to memorialize Congress to this effect. This committee met immediately following the adjournment of the asso-

ciation and prepared a memorial of some two pages. This was presented to the House of Representatives by General James A. Garfield, Congressman from Ohio, on February 14, 1866. At the same time he presented a bill establishing the National Bureau of Education. In the debates which followed it was suggested that a department instead of a bureau be created, and this bill received 80 votes in its favor with 44 against it in the House on June 19, and was sent to the Senate. Here it came before the committee on the judiciary, was favorably recommended, and on March 1, 1867, it passed without a division. The following day it was signed by President Johnson, and on March 14, 1867, Henry Barnard became the first commissioner of education.

The functions to be performed by the new office were defined in this original act as follows: "to collect statistics and facts showing the condition and progress of education in the several States and Territories, and to diffuse such information respecting the organization and management of schools and school-systems, and methods of teaching, as shall aid the people of the United States in the establishment and maintenance of efficient school-systems, and otherwise promote the cause of education throughout the country."

The fact that the original bill had called for "bureau" and a "department" had been created aroused some Congressmen against it. Moreover, some schoolmen failed to understand the act. There was so much opposition that in the appropriation act passed on July 20, 1868, a provision was inserted abolishing the Department of Education as a separate unit and recreating it as an Office of Education in the Interior Department. This bill also reduced the salary of the commissioner from \$4,000 to \$3,000 a year. This act became effective on July 1, 1869. Dr. Barnard at once tried to arouse the educational



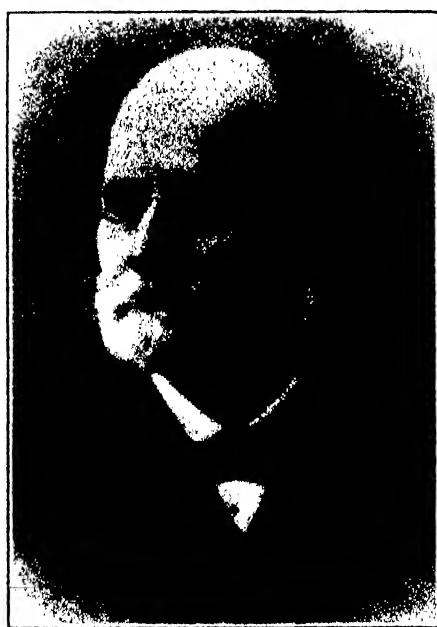
NATHANIEL H. R. DAWSON
COMMISSIONER OF EDUCATION, 1886-1889

associations to protest to Congress. When, however, there seemed to be general apathy on the subject, he resigned, effective on March 15, 1870.

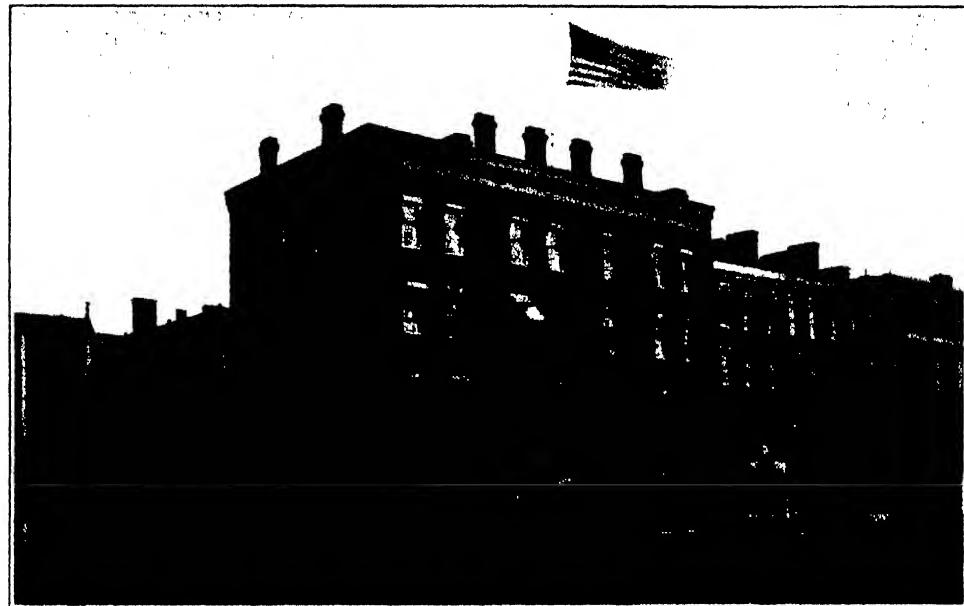
Dr. Barnard had faced an almost impossible task. The elementary schools in the North had suffered during the war, and those which had existed in the South had been completely wrecked. The "New West," which was rapidly settling up, needed much aid in shaping its schools. To do all this work the commissioner was given a force of but four employees and funds amounting to slightly in excess of \$12,000 to cover salaries and expenses for two years. With this meager allotment he made an extensive survey of the schools of the District of Columbia. But the work which he did as commissioner consisted of examining the history of educational experiments, the dismissal of educational reformers and the biography of great teachers. During most of the time that he was in office the Secretary of the Interior was hostile to him. The *Congres-*

sional Globe of November 30, 1868, quoted the secretary as favoring the elimination of the Department of Education on the ground that there was no necessity of knowing anything whatsoever about it. Nobody had ever come to an office with greater enthusiasm and more practical experience than Dr. Barnard brought; nobody ever met with more disheartening experiences than he did.

When he retired on the 15th of March, President Grant appointed General John Eaton, of Tennessee. He was destined to serve for more than 16 years. He possessed ability to get cooperation from the Congress, which Barnard had failed to do. In his addresses to the National Education Association he called attention to the powers of his office. On the negative side of the question he said, "The National Government should take no action calculating to decrease local or individual effort for education. It is of the individual and by the individual but it is for all men."



WILLIAM TORREY HARRIS
COMMISSIONER OF EDUCATION, 1889-1906.



OFFICE OF EDUCATION IN THE TIME OF DR. HARRIS.

LOCATED ON NORTHEAST CORNER OF EIGHTH AND G STS. OPPOSITE THE OLD BUILDING OF THE
DEPARTMENT OF THE INTERIOR.

The National Government in its relation to public education may not suffer either the local or general problems of ignorance that shall result in the destruction of the principles of liberty by the centralization of power." On a platform similar in content every commissioner of education has stood. These principles have served as a guide for the work which should be performed in the office. Eaton represented the Department of the Interior at the Centennial Exposition in 1876, was chief of the Department of Education for the New Orleans Exposition, and was president of an International Congress of Education held there. During his term the library was very largely increased. In 1870, in addition to Dr. Barnard's books, there were not over 100 volumes. But when Eaton left there were 18,000 bound volumes and 47,000 pamphlets. Moreover, the assistants in the office had increased from 2 to 38, for during his term statistical work had been begun and the educational service in Alaska assumed.

He resigned on the 5th of August, 1886, and Nathaniel H. R. Dawson, of Alabama, was appointed by President Cleveland. Colonel Dawson began his new work on September 27. Many criticisms were leveled at this appointment, not at the man nor his personal qualifications, but at his lack of educational qualifications for the office. Recognizing this, he endeavored to select as his assistants people of practical experience in education. Under his personal direction a series of monographs on the history of education in the several states was begun. Some of these, prepared under the direction of the history department of Johns Hopkins University, are still authentic documents in the field.

Dawson resigned on September 3, 1889, and was succeeded by William Torrey Harris, of Massachusetts, who had been superintendent of schools in St. Louis, Missouri. Dr. Harris was an outstanding commissioner. He was the American authority on the works of Hegel, and his explanations of Hegel's

philosophy won him an honorary Ph.D. degree from a German university. When Spencer's "First Principles" appeared, Harris wrote a review, but unable to find a journal which would accept it he founded *The Journal of Speculative Philosophy*, which he edited from 1867 to 1893. During his term the work in foreign education was begun and took on very great importance. It was also while he was commissioner that the second Morrill Act was passed. He had not only the longest term in the history of the office, but also when he came in was so well known from the point of view of his leadership and his grasp on education that correspondence which came into the office asked the commissioner's opinion rather than the opinion of the office itself. Incidentally, this tendency proved in the long run a weakness, for it made virtually all the assistants in the office merely adjuncts of the commissioner, and when he grew old and was unable to give to the work the same attention that he did at first,



DR. PHILANDER P. CLAXTON
COMMISSIONER OF EDUCATION, 1911-1921.

the office suffered. He also failed to give sufficient attention to Congress, with the result that his successor found the committee on education entirely out of touch with the work of the office.

When Dr. Harris aged and his health began to fail, the matter of a retirement salary for him was taken up by his friends with the Carnegie Foundation for the Advancement of Teaching. When they were ready to give him a pension he resigned on June 30, 1906, and was succeeded by Elmer Ellsworth Brown, of California. Brown immediately gave his attention to the problems of internal organization, securing a man from the Congressional Library to put the library of the Office of Education on a workable basis; brought the reports, which were from one to three years late, up to date, and began the issuance of a series of bulletins which had been authorized 10 years before. He brought the office work to the attention of the Secretary of the Interior and Congress and attempted to secure for the office



DR. ELMER ELLSWORTH BROWN.
COMMISSIONER OF EDUCATION, 1906-1911.

additional specialists in various fields. Some of these he obtained. The specialists in higher education, rural schools, school hygiene and industrial education and the editor-in-chief were obtained at this time. In addition, a lump sum of \$6,000, the first the office had ever enjoyed, and which became available after he had left the office, was granted. The salary roll increased during his term almost \$20,000, and the commissioner's own salary was advanced from \$3,500 to \$5,000. In May, 1911, he submitted his resignation to become effective on June 30 following, on which date he became chancellor of New York University. He was succeeded by Philander P. Claxton, of Tennessee.

Dr. Claxton had come from his work in North Carolina and Tennessee with all the enthusiasm of a missionary. He was an authority on the rural school and greatly strengthened the work of the division. During his time, however, came the great world war, and with it a large number of a-dollar-a-year men and women were appointed. Occasionally people were put on the payroll at a dollar a year and given appointments on the staff who were really paid secretaries of educational organizations. At this time, the work of this office may be said to have been (1) to collect expert opinion and statistics on education and to disseminate these among the several states; (2) to serve as an expert adviser to local governments and to colleges on educational matters; (3) to conduct research in education; (4) to approve the allotments to and the disbursements of the land-grant colleges under the Morrill-Nelson acts; (5) to direct the educational processes for the natives of Alaska; (6) to superintend the reindeer industry of the Alaskans; and (7) to furnish medical aid to the natives of Alaska. Of these duties the last four groups may be said to be administrative; the first three are essentially research.

There had been added during Dr. Claxton's administration a number of specialists for war work, and such work also involved almost the full time of some of the other specialists. For instance, the division of home economics did a great deal of work in connection with the preparation of foods which people in this country had to use while their own white flour was being shipped abroad. It had also a big field in the war propaganda. Another large field of work was the encouragement of school gardens used to produce food for Americans, while food commercially produced was shipped abroad. Thrift stamps had to be sold, instruction in citizenship worked out, and an effort made to get foreigners naturalized. In all this work the Office of Education was exceedingly active. A travel fund had been voted by Congress which enabled Commissioner Claxton to visit many parts of the country and be addressed associations on the work of the war especially.

In June, 1921, he resigned and John James Tigert assumed responsibility. At this time much of the work which Claxton had done was eliminated. Appropriations for printing were reduced and expenses of government in other respects were curtailed. All the dollar-a-year men were dropped or taken over as assistants in the commissioner's office. The citizenship work, which had been going on under Dr. Dunn, was assumed by the American Red Cross. During this administration the Bureau of the Budget was created and every effort was made to hold down the expenses.

On the 31st of August, 1928, Commissioner Tigert resigned to become president of the University of Florida. The present commissioner took office on the 11th day of February, 1929. After a brief study of the situation it was decided to make the office essentially a research office, which it had been at the time of its creation. The name "Bureau



DR. JOHN JAMES TIGERT
COMMISSIONER OF EDUCATION, 1921-1928.

of Education," which had been used in the appropriation acts and for which there was no other authority, was abandoned in favor of Office of Education on an order of the Secretary of the Interior.

The commissioner visited Alaska the first summer he was in office and investigated the schools and other work as far as he was able. This convinced him that Alaskan affairs could not be successfully handled by the Office of Education. Accordingly, on November 1, 1929, by order of the Secretary of the Interior, the reindeer service was transferred to the Governor of Alaska, thereby placing it in the hands of a local officer who could give it the necessary attention promptly. During the formulation of the appropriation act of 1930 he made an effort to have the education of the natives of Alaska transferred to the commissioner of education of the territory. In this, however, he was unsuccessful, largely for the reason that members of Congress desired some

Federal officer to be responsible to them for the expenditure of the funds. It was then decided to have the education and the medical service for the Alaskans transferred to the Indian Office, which has supervision of matters relating to the Indians in continental United States. In the second deficiency act of 1930, this was also accomplished. With this transfer of work the assistant chief clerk and the assistant head of the Alaska division were transferred to the Indian Office. From this time on the Office of Education had only the allotment and disbursement of land-grant funds in addition to the original research functions for which it was created.

In order to discharge the research functions the office was reorganized into five major divisions. These were: Administration, under the chief clerk; publications, under the editor-in-chief; research and investigation, under the assistant commissioner; the library, under the librarian; and the service



DR. WILLIAM JOHN COOPER
COMMISSIONER OF EDUCATION, 1928-

division, under the chief of that division. This last division includes all those specialists whose field lies in more than one of the other divisions. It also covered the surveys of states and cities which had been begun in Commissioner Brown's time and which had been found useful to the office in keeping its members closely in touch with affairs in the field.

The major division of research and investigation was further subdivided into five minor divisions: (1) A division of colleges and professional schools which succeeded to the work formerly handled by the higher education division. This involves certain special statistics of the colleges and universities, the land-grant college statistics which are required by law, dealings with the professional associations and surveys of institutions or of states so far as the collegiate institutions are concerned. (2) The division of American schools which succeeded to the work of the former city schools division, and also to that of the rural schools division in so far as these rural schools presented similar problems. (3) The division of special problems which took over the rural school problems of transportation and other problems due chiefly to sparseness of population, and added to these the education of children who are physically or mentally handicapped and those who are supernormal. To it also were assigned Negro education, which had existed as a division in Commissioner Claxton's time, and the education of indigenous peoples, as the Office of Education had control of the natives of Alaska for 40 years and had made great progress in the vocational education of these people, but had not really made a fundamental psychological study of them. (4) The division of statistics which had grown up gradually; and (5) the division of foreign schools which had only about half enough assistants.

As soon as it is possible for Congress

to vote more money, we wish to add to the divisions the following specialists: To the service division, a specialist on extension education; to the division of American schools, a specialist on school supervision; to the division of special problems, an expert in the education of indigenous peoples; and to the foreign schools division, two experts—one on the schools of the Orient and another on the schools of Spanish America. The addition of these five specialists will make the Office of Education a reasonably efficient workable organization. To them should be added a few assistants.

In making the office a strictly research organization, it became necessary to get funds from Congress to pursue the following projects. The first one attempted was a National Survey of Secondary Education, authorized by Congress in 1929. It was decided to have a new division in the office whose personnel would be temporary, with the exception of one man who would be the man regularly employed in the office for that piece of work. Two hundred and twenty-five thousand dollars were appropriated to be spent over a period of three years. It was found upon investigation of the plan submitted by the National Committee on Research in Secondary Education that it would give no information on the history of secondary education, on the aims and purposes of education, on teachers of secondary schools or on the costs of such schools. It was decided, however, to omit the history of education. The aims and purposes of education, it was felt, would be largely copies of the cardinal principles which were published by the office in 1918. The teachers and the costs of secondary schools could be gathered in other surveys along with the costs and teachers in other schools. Accordingly, the survey gave its attention to the curriculum, the extra curriculum, the organization of administration, guidance and similar problems. Dr. L.

V. Koos, of the University of Chicago, an outstanding man in the field of secondary education, was made part-time associate director and was allowed to build up his staff both with part-time and full-time workers. The money was appropriated, \$50,000 for the first year, \$100,000 for the second year and \$75,000 for the third year. These amounts included the printing, as well as all other expenses of the survey.

In 1930 Congress authorized \$200,000 for a survey of the education of teachers. This also was distributed over a three-year period, but for the third year the appropriation was cut by \$20,000, making \$180,000 available for the entire study. Likewise for this survey the member of the staff who had teacher education in hand was assigned as coordinator. Dr. E. S. Evenden, of Columbia University, was obtained as part-time associate director. The work of this survey will be practically finished on June 30 of this year.

The third survey, in school finance, was approved in 1931 for \$350,000, distributed over a four-year period. Dr. Paul R. Mort, of Columbia University, was secured as part-time associate director, and the specialist in school finance in this office was assigned as the coordinator. At the end of the first year of this study, the financial crisis made it desirable to balance the budget. In attempting to do this Congress eliminated this study entirely. As a result only

one volume, a bibliography of educational finance, was published from Government funds. Of the five fields which had been outlined for investigation, one only could be brought to a conclusion and to do this required more funds. In this emergency the General Education Board's executive committee granted us all the money which the committee could grant. With this fund two more volumes are being published: One, on the state support of schools, will bear the imprint of Teachers College, Columbia University, and will be widely distributed free. All other problems which had been started in the other four fields will be published under an imprint of the American Council on Education and sold to persons who are interested. This volume will be entitled "Research Problems in American School Finance."

While the depression has temporarily put a stop to this special survey work, which was directed by the commissioner personally, it is hoped that when the government finances are in better shape it will be possible to resume surveys of this sort.

A survey of special education had already been discussed and approved by the state superintendents of public instruction. A survey of elementary education was in the process of formulation. These two surveys as well as the study of school finance should be taken up as soon as funds permit and carried to a conclusion.

SADI NICHOLAS LÉONHARD CARNOT

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SADI NICHOLAS LÉONHARD CARNOT was born in Paris on the first day of June, 1796, the eldest son of the noted French mathematician, Lazare Nicholas Marguerite Carnot. Surrounded by a family whose members through several generations had held political and military posts of the first importance, Sadi Carnot's brief life was denied no essential for brilliant achievement. It was natural that he should display the mental acuity that was a family characteristic, although his latent abilities did not find their proper outlet until after he had left the fields in which his forbears had found lasting fame and turned to scientific investigations.

At the age of sixteen years, Sadi entered the École Polytechnique, having in view a career as a military officer. Two years later he went out from the institution commissioned as an army engineer and with excellent prospects for promotion, but the downfall of the Empire and the Bourbon Restoration brought such family reverses that he left this branch of the service in disgust. The duties assigned to him under the changed régime were not only irksome, but they allowed no time for private study and offered little hope for improvement in the future. Consequently, in 1819, Carnot turned to the staff corps, where he won a lieutenancy on his showing in the usual examinations.

It was during the next few years that his health seems to have been undermined beyond repair, so ardent was his application in the pursuit of knowledge. His studies took him into the fields of mathematics, physics, chemistry, natural history, political economy, music and the fine arts in general. Apparently, he

drove himself without mercy. Long periods of intense study were broken only by like excesses in athletics, especially swimming and fencing. His physique was never robust, and it was inevitable that such continued and heavy demands on both mind and body should lead to a final breakdown.

For a number of years cholera had been epidemic throughout the Far East, India and Asia Minor. In January, 1832, it reached London, and soon thereafter it appeared in France, Spain and Italy. It was during this year that Carnot fell a victim to scarlatina, which ran into brain fever. And then, before he had fully recovered, he was overtaken by the dread Asiatic epidemic, and he died in Paris on August 24, 1832. Thus, after a span of only thirty-six years, ended the physical career of "one of the most original and profound thinkers who have ever devoted themselves to science."

To appreciate the justification for such a sweeping assertion, it is necessary to survey not only his own work, but also some of the theories of his predecessors, and the remarkable developments that have followed during the century since his death.

From ancient times there have been numerous speculations concerning the nature of heat. For present purposes these may be grouped under two general theories. One of these regarded heat as a fluid substance, and, although it was overthrown during the first half of the nineteenth century, our present terminology retains many reminders of this view-point, such as "flow of heat," "quantity of heat," etc. The other theory, possibly equally ancient in its



From a portrait by Bailly.

SADI NICHOLAS LÉONHARD CARNOT (1796-1832)

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beginnings, regarded heat as some sort of motion. Plato (427-347, B. C.) declared that heat and fire are themselves due to motion. Several hundred years later, Titus Carus Lucretius (95?–55, B. C.), a Roman didactic author, wrote a remarkable poem entitled "De Rerum Natura," and in it he discussed heat as a kind of substance. In his "Novum Organum," Francis Bacon (1561-1626) declared that "heat is motion"—it is the movement of the "perpetually quivering" small parts of bodies. This latter view seems to have been accepted by the majority of Bacon's English followers, although in Continental Europe many philosophers still preferred to regard the heat in a body not as the motion of its own particles, but rather of the particles of a peculiar fluid that found ready passage through the pores of the body. To account for various observed phenomena, this fluid was regarded as a highly elastic and very subtle substance. However, in 1664, Robert Hooke, in his "Micrographia," stated that heat is "nothing else but a very brisk and vehement agitation of the parts of a body." Apparently, this view was not uncommon during the seventeenth century, numbering among its adherents Descartes, Amontons, Boyle and Newton.

In spite of these leanings towards the modern energy theories, many philosophers during the seventeenth and eighteenth centuries clung to the material theory of heat. In 1756 Joseph Black, who was professor of chemistry at Glasgow University, investigated the problem of the disappearance of heat when ice melts and when water boils. Such a change of state is not in itself accompanied by a change in temperature, although a large amount of heat is absorbed in the process. Black regarded heat as a fluid substance, and he came to the conclusion that its disappearance was due to a sort of chemical union with the substance being melted or boiled.

Hence, he termed this heat "latent," i.e., hidden, as distinguished from the "sensible" heat that affects a thermometer. We now know that there is no "latent" heat, but merely a transformation by which the thermal energy being supplied to cause the melting or the evaporating increases the potential energy of the particles of the substance. Nevertheless, the material theory of heat seemed to have gained some support, and, considering the dearth of conclusive experiments, it is not surprising to find it widely accepted in Carnot's time. The temperature of a body was thought to depend on the quantity of heat-substance or "calorie" it contained. At the same time it was believed that the total quantity of calorie in the universe was unalterable. Some investigators believed that thermal conduction was due to the self-repellent characteristic of the particles of calorie, perhaps aided by an attractive force between them and the particles of the conducting body. Naturally, calorie was at first believed to possess the common characteristic of all matter, namely, weight, but in 1799, Count Rumford made his famous "Inquiry Concerning the Nature of Heat," in which he carried out a series of painstaking and delicate experiments that brought him to the conclusions that "a body acquires no additional weight upon being heated, or rather, that Heat has no effect whatever upon the weight of bodies," and furthermore that "all attempts to discover any effect of Heat upon the apparent weights of bodies will be fruitless." Rumford further decided that it is "extremely difficult, if not quite impossible, to form any distinct idea of anything capable of being excited and communicated in the manner the Heat was excited and communicated in these experiments, except it be motion." In other words, he regarded the heat generated in his tests as a transformation of the work done in its production.

At about the same time that Rumford was carrying on these investigations, Humphry Davy succeeded in melting two blocks of ice by merely rubbing them together so that their friction was the only source of the heat causing the melting. The conclusions seemed unavoidable, and the calorists were forced to accept them in part, at least in so far as the question of the weight of heat was concerned, and thus it was that caloric became one of the imponderables.

Still there were others, who, like Rumford, had a growing suspicion that there was a definite relation between work and heat. Ignorance of this relationship, or, as we now say, of the principle of the conservation of energy, had for centuries led many serious workers to attempt the making of perpetual motion machines. Nineteenth century experimental technique had to undergo several decades of development before the mechanical equivalence of heat could be determined with such quantitative precision as to bring universal acceptance of an energy theory. When, however, it finally became certain that heat was not a material substance, and that energy could only be transferred, the search for self-motivating devices that also should act as perpetual sources of power came to an end, so far as intelligent investigators were concerned. But before leaving the point, it should be noted that the actual measurement of the equivalence between work and heat was a step quite distinct from the recognition of the immaterial nature of heat.

At the time when Carnot began his famous investigations in this field neither the non-material nature of heat nor its mechanical equivalence had been demonstrated conclusively. Being an engineer, he naturally was interested in the problem of how much work might be obtained from a steam engine. He not only began by accepting the still-prevalent caloric theory, but also the doctrine of its conservation, although the experiments of

Rumford and Davy had indicated that heat was actually generated. And yet, we scarcely can say that these views were serious handicaps, for he saw that the basic problem was one of much wider application than to the steam engine alone. Its treatment should be general enough to embrace all heat motors, of any type whatsoever—a conviction that was expressed early in his paper of 1824. Although this was his only publication, the “*Reflexions sur la puissance motrice du feu et sur les machines propres à développer cette puissance*” stands as a classic, because of its keen analytical style, as well as the importance of its conclusions. Carnot began by declaring that “in order to consider the generation of motion by heat in all its generality, it is essential to reason independently of any particular mechanism or special agent; the conclusions obtained must be applicable not only to the steam engine, but to any imaginable heat motor, whatever be the working substance employed, or the method of its use.” When one considers the possible scope of such a problem, it is not surprising that its solution over a hundred years ago should have had a wide influence upon the developments of the century that now has elapsed.

In building up his general argument, Carnot discussed the performance of the steam engine in some detail. He maintained that the production of motion is always accompanied by the restoration of thermal equilibrium, *i. e.*, by the passage of heat from a hot body to a cooler one. Thus, he pointed out that in the steam engine

the heat produced by combustion penetrates the walls of the boiler, and generates steam, in which it becomes incorporated, so to speak. This steam carries heat with it to the cylinder, where it does a certain amount of work, and from there passes on to the condenser, where it is condensed by contact with the cold water. In this final stage the heat that was generated by the combustion is absorbed by the cold water of the condenser. It is heated by means of the

steam just as if it had been placed directly over the fire. The steam is only a medium for the transfer of the heat.

Carnot believed that it was the transfer of heat rather than its destruction that resulted in work. On this point he said:

The generation of motive force in a steam engine is not due so much to the actual consumption of heat, as to its passage from a hot body to a cold one, i.e., to the restoration of its equilibrium, which by some means, such as chemical action, combustion, or in any other way, has been disturbed.... This principle applies to all machines that are set in motion by means of heat.

Again:

In general, whenever a temperature difference exists, and where it is possible to restore temperature equilibrium, a moving force can be produced. Steam is one means for acquiring this force, but not the only one; all substances in Nature can be used for this purpose; all are subject to volume changes, successive contractions and expansions with alternations in their warmth and coldness; by these volume changes, all are capable of overcoming certain amounts of resistance, and in this manner of producing moving forces. A solid body, such as a metal rod, increases and decreases in length if it is alternately warmed and cooled, and it is able to move bodies attached to its ends. A fluid that is alternately heated and cooled undergoes an increase or a decrease in its volume, and can move bodies of considerable weight that may oppose its expansion. Temperature variations produce large changes in the volume of a gas if it is in a flexible container, such as a cylinder provided with a piston, and can produce considerable movement. The vapors of all substances that can exist in the gaseous state . . . may be used in the same manner as steam.

The above statement shows clearly that at the time it was written (1824), Carnot had in mind only the transfer of heat without loss, from a higher to a lower temperature. He was thinking of the falling of a material substance (caloric) from a given temperature level to a lower one, whereby it is enabled to do work, just as water turns a wheel by falling from a height without any alteration in its quantity. However, in some of his later miscellaneous notes, which were

first published in 1878 by his brother, L. H. Carnot, there is evidence that he afterwards abandoned this idea of the conservation of heat, and gave some thought to the "mechanical equivalence" of the heat used in doing the work. These notes also show that somewhat prior to 1832 (the time of his death) he had acquired a true conception of the nature of heat, and had projected a number of experiments similar to those actually performed years later by J. P. Joule in determining the numerical value of the mechanical equivalent of heat, that is, the number of foot-pounds of work necessary to raise the temperature of one pound of water through one Fahrenheit degree. His plans even anticipated the famous "porous plug" experiment of Joule and Thomson.

However, we must bear in mind that at the time the "Reflexions" was written, Carnot insisted on the conservation of the heat employed in the cyclic transformation in a heat motor. His emphasis on this point is best appreciated by reading his own words:

In our considerations we must insist that if a body undergoes any changes, and, after a series of transformations, returns to its original condition of density, temperature and molecular state, it then contains the same quantity of heat as it had originally,—in other words, the quantities of heat absorbed and evolved during the various transformations completely balance one another. This fact has never been doubted; at first it was accepted without reflection; later it was verified by numerous calorimetric experiments. To deny this is to set aside the entire theory of heat, of which it is the basis. However, it may be remarked that the principal foundations on which the theory of heat rests stand in need of much more thorough investigation. The theory in its present state is unable to explain numerous observed facts.

The latter part of this quotation might lead one to think that Carnot was about to abandon the caloric theory in favor of one based on the doctrine of the conservation of energy, but perhaps this would be reading into his words more

than is justified by the state of his speculations at the time, because, throughout his paper he uses the words "heat" (*chaleur*) and "caloric" (*calorique*) interchangeably.

In the more significant part of his paper, Carnot discussed in detail the changes occurring when the working substance is carried through a complete cycle of transformations, as follows:

Let us consider an elastic fluid, such as atmospheric air confined in a cylinder that is provided with a movable partition or piston. . . . Also let there be two bodies, A and B, each of constant temperature, that of A being higher than that of B. Now imagine the following series of operations to be carried out:

1. Place the body A in contact with the wall of the chamber containing the air; we assume that it transmits heat easily. As a result of this contact, the air acquires the temperature of the body A.

2. The piston rises steadily. The body A is kept in contact with the (cylinder containing the) air, whereby the air is maintained at a constant temperature during its expansion. The body A supplies the heat (*calorique*) necessary to keep the temperature constant.

3. Now the body A is removed, and the air is no longer in contact with a body that can supply it heat; however, the piston continues to advance. The air is rarefied, without acquiring more heat, and its temperature falls. We will assume that it falls to that of the body B; at this point the piston comes to rest.

4. Now place the air (chamber) in contact with the body B; the air is compressed by pushing the piston down. However, it now remains at a constant temperature, because it is in contact with the body B to which it gives up its heat.

5. Now the body B is removed, and the air is still further compressed, which produces a rise in temperature because it is now isolated. The compression is continued until the temperature of the air reaches that of the body A.

6. Now the air is again placed in contact with the body A, and the piston returns to the position previously reached under Operation 2.

7. The step described under 3 is repeated, and the other steps follow in the succession: 4,5,6, 3,4,5,6, 3,4,5,6, etc.

During these various operations, the piston is subjected to a greater or less pressure by the inclosed air; the elastic force of this air varies partly because of changes in volume, and partly because of variations in temperature; but it should be observed that for equal volumes, *i.e.*, for similar positions of the piston, the tempera-

ture is higher during a movement of expansion than when the movement is one of compression. Hence, during the former, the elastic force of the air is greater, and thus the force resulting from the expansion is larger, than that employed in compression. Hence, there is a surplus of motive force, which may be employed as desired. The air has served as the working substance; it has been used in the most advantageous way possible, because no unemployed restoration of equilibrium has taken place.

This series of transformations constitutes what is known as Carnot's Cycle. As here used, a "cycle" means a chain of operations to which a given quantity of a substance is subjected, so as to return entirely to its initial state. It must be remembered that Carnot was not reasoning in accordance with the principle of the conservation of energy. Heat measurements, always difficult, were far cruder in his time than they are now, and he knew of no reason for not thinking that the amount of heat given out by an engine is the same as that which it has received. It was not until long after Carnot's time that experiments were performed which proved definitely that an engine does not give out as much heat as it receives. When a theoretical working substance that has ideal characteristics is carried through a cycle and returned identically to its initial condition, it is unnecessary to consider changes in its intrinsic energy, but with any actual working substance this is not the case. Nevertheless, Carnot was able to show that a "reversible" engine, working between two given temperatures, would have the greatest efficiency possible; hence, greater than that of any real engine, which, of course, is not reversible. He proved that the efficiency of this idealized engine depends only on the temperatures between which it works, *i. e.*, on the difference between the temperature of the source (T_1), and that of the condenser (T_2). Thus, the efficiency is given by $E = (T_1 - T_2)/T_1$.

In 1854 the German physicist Clausius showed that Carnot's conclusions,

based on the idea of the reversible cycle, were still applicable and useful, although they had been conceived in ignorance of the true nature of heat. Only slight modifications were necessary to adapt them to the newer dynamical theories, and thus they became important and permanent features in the science of thermodynamics. He pointed out that Carnot was the first to observe that when mechanical work results from a thermal process, heat passes from a hot to a cold body—and, conversely, heat can be made to pass from a colder to a hotter body by the expenditure of mechanical work. Clausius then carried the reasoning a step further and stated that "heat can not, of itself, pass from a colder to a hotter body," a generalization known as the Second Law of Thermodynamics.

In the light of modern thermodynamic theories, Carnot's investigations seem exceedingly simple, but their influence has shown that they had the qualities of inspiration. He not only denied the possibility of perpetual motion, but in suggesting a new method of analysis, he contributed incalculably to the theoretical and practical advances made during the latter half of the nineteenth century. Neither he nor any of his contemporaries could have foreseen the wide application of the principles which he enunciated. Innumerable investigations based on his

pioneering work have shown that the processes of the entire physical universe involve the evolution or the absorption of heat. In its scope, the second law stands as one of the greatest generalizations of all time. Willard Gibbs was able to show that it is involved in every chemical reaction. Biologists have found it to be a controlling factor in both the physical and the chemical processes that distinguish living from dead matter. In the words of a modern physicist, "it must be regarded as one of the most firmly established of scientific facts."

The hundred years that have elapsed since Carnot's labors came to an end have witnessed to an unparalleled degree the manner in which one's work may live on after he is gone. Recalling once more that his conclusions were based on an erroneous doctrine concerning the nature of heat, and then surveying the practical developments that have grown out of his investigations to enrich the century and all future time, we can not deny him the credit due to a real pioneer. He opened up a region of permanent and ever-increasing value to the human race. It is inconceivable that later centuries will not see even wider applications of the principles and methods of investigation pointed out in 1824 by the young French engineer, Sadi Carnot.

ESSENTIALS OF THE GENERAL RELATIVITY THEORY

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ORIGIN AND CHARACTERIZATION OF THE GENERAL RELATIVITY THEORY

THE general relativity principle may be stated provisionally as follows: All systems in any kind of motion are equivalent for formulating the laws of nature. This means that all motion is relative in contradistinction to the special relativity principle,¹ according to which only uniform rectilinear motion is relative.

The basis of the general principle is the discovery that gravitation, *i.e.*, the tendency of a body toward any other body, and inertia, *i.e.*, the disposition of a body to resist a change of its state of motion, are but different manifestations of the same quality of matter. What led to this discovery is the circumstance, known but unheeded before the relativity theory, that the gravitational mass and inertial mass of a body are equal. From the equivalence of gravitation and inertia was deduced the principle of equivalence: Acceleration in one direction due to any force is equivalent in its effects to acceleration in the opposite direction due to gravitation. This principle is of great value in the investigation of the gravitational phenomena. Accelerated motion produced by a force at our command is examined in a laboratory. The results obtained can be applied to gravitation by reason of the equivalence principle. The general

relativity theory turns upon this principle and is thus, on the whole, a new theory of gravitation. To gain an insight into it we have to know first how the general relativity principle of which the equivalence principle is a special form can be maintained against strong objections to it.

VINDICATION OF THE GENERAL RELATIVITY PRINCIPLE

The phenomena of the jolt and of the centrifugal forces are apparently incompatible with the general relativity principle. The passengers in a train moving uniformly on a straight track may consider the train and everything in it to be at rest and the world outside of it to be in motion. But when the train suddenly changes its velocity or makes a turn, that is, when it undergoes an acceleration, the passengers receive a disagreeable jolt, a pull backwards, forwards or sideways, and objects in the train are thrown about. The passengers can then no longer deceive themselves by imagining the train to have remained at rest and its surroundings to have suddenly moved, thereby producing the disorder. Likewise rotary motion is recognizable by centrifugal phenomena. From the rapidly turned grinding-wheel spurts the water with which it is wetted. A pliable sphere rotating swiftly becomes flattened at the poles. The phenomena of the jolt and centrifugence consequent upon acceleration and rotation indicate non-uniform motion and identify the system where it is observed. Their cause can lie only in this system and nowhere else. This marks non-uniform motion as absolute

¹ Acquaintance with the special relativity theory is necessary to understand the general one. Those uninformed are referred to the writer's essay published in the SCIENTIFIC MONTHLY for January, 1932, under the title "Fundamentals of the Relativity Theory" and obtainable from the writer as a reprint.

and furnishes a strong argument against the general principle.

But there is a more potent counter-argument. Suppose the train, the grinding-wheel, the pliable sphere remain at rest and the universe about them undergoes an acceleration. Are we then sure that objects in the train would not be shaken, the water not spurt from the wheel, the sphere not become oblate? The possibility of these phenomena of the jolt and centrifugence occurring under the assumed condition can not be excluded. Hence they are not sufficient to mark non-uniform motion as absolute. Their cause may be in the universe around the system where they are observed; they would appear if the system remained at rest and the universe were accelerated or revolved around it. The phenomena of night and day justify this reasoning. They may be due either to the earth rotating against a stationary firmament or to the firmament revolving around the stationary earth. The second view was the accepted one until Copernicus replaced it by the first one. Non-uniform motion is therefore relative as postulated by the general principle.

EQUALITY OF GRAVITATIONAL MASS AND INERTIAL MASS

The general relativity principle thus rests first upon the assumption that the masses of the universe exert a force upon any system. Such a ubiquitous force in nature is gravitation. Newton recognized it and established its law: Any two bodies tend toward each other with a force equal to the product of their masses divided by the square of their distance. He conceived gravitation and other forces to act across empty space without intermedium. Modern physics does not acknowledge this "action at a distance" but assumes that a body imparts to the space about it certain qualities by means of which it in-

fluences other bodies.² This altered state of the space is called a field. Its intensity diminishes with the distance and finally vanishes. The sun's gravitational field reaches until the remotest planet.

The second factor necessary to uphold the general principle is the equivalence of an accelerating force to gravitation acting in the opposite direction (equivalence principle). The observable effects are the same in both cases. An accelerated system is therefore replaceable by a small part of a gravitational field. This is proved through the close connection between gravitational mass and inertial mass.

All bodies in a vacuum fall to the earth with the same acceleration designated by the letter g . It follows from this that the gravitational mass (m) and inertial mass (m_i) of a body are equal. The former is the ratio between the weight³ of the body and the gravitational acceleration: $m = W/g$. The inertial mass is the ratio between any force and the acceleration it produces: $m_i = F/a$. We use the weight as the accelerating force, that is, we let the body fall in a vacuum, then we obtain: $m_i = W/a$. Since all bodies fall with the acceleration g , the factor a in the last equation is to be replaced by g ;

² These qualities are unknown and nowise explained by being designated as "space curvature." For this term is meaningless. (See below.)

³ Weight is the pressure exerted by a body on something under it which prevents it from falling. It must not be confounded with gravitational mass. Weight and gravitational acceleration vary with the place on the earth, but gravitational mass, the ratio between the former and the latter, does not. That ratio in a body weighing one kilogram in Paris is 0.10195 everywhere on the earth. The equality of gravitational mass and inertial mass can not be inferred solely from the circumstance that they are always proportional. Two things which are always proportional need not be equal at all. Weight and width of a plate are always proportional, yet they can not be designated as being equal.

hence we obtain: $m_1 = W/g = m$. The law of the equality of gravitational mass and inertial mass is thus proved. This universal law, as can easily be shown, is the reason why all bodies fall equally fast.

The equality of gravitational mass and inertial mass was known long before the relativity theory, but was considered as something accidental and unimportant. When its vast significance and the close connection between gravitation and inertia as different manifestations of the same quality of matter were discovered, the general theory developed. The bearing of this discovery upon the theory is elucidated through the following illustration.

EQUIVALENCE OF AN ACCELERATED SYSTEM TO A SMALL PART OF A GRAVITATIONAL FIELD ACTING IN THE OPPOSITE DIRECTION

The room of a physicist is transferred to the interstellar space, where there is no gravitation. Objects exert here no pressure on his hand and remain floating in any spot where he lets them loose. A thing thrown towards one of the six walls moves with steady velocity and remains on it at the point toward which it was directed. A cord attached to the ceiling is not stretched by a ball fastened to its other end. The physicist, knowing that he is in a space free from gravitation, does not wonder at these phenomena, since they are characteristic of such a space.

A mysterious being begins to pull the room upwards with steady force by a rope attached to the roof. An observer outside of the room sees it now flying upwards with continually growing speed. For a steady force produces acceleration. The physicist, however, is not aware of this motion because he participates in it. But he notices a sudden change in the behavior of the objects in the room. They have weight and fall to the floor when let loose, all

with the same acceleration. The cord attached to the ceiling is stretched by the ball.

Puzzled at this sudden change he looks about for its cause and discovers the rope. Now he believes to have found an explanation. A heavenly body has appeared below the room, and the latter is now in the body's gravitational field, held in position through the rope by some power above. On second consideration, however, he finds that there is also another explanation. A power above has suddenly begun to pull the room upwards. This accounts for the change of the phenomena.

Each explanation is fully adequate. It is impossible to decide whether the room is at rest in a gravitational field acting downwards or under the influence of an accelerating force directed upwards. This proves logically that an accelerated system and a small part⁴ of a gravitational field acting in the opposite direction are equivalent in their effects and that accelerated motion is relative.

This proof rests upon the law of the equality of gravitational mass and inertial mass, due to which all bodies fall equally fast in a gravitational field. In our imaginary experiment all objects approach the floor with the same acceleration because they remain in their position and the floor is pulled towards them. If bodies did not fall equally fast in a gravitational field, that motion of the objects could be explained only by a pull of the room upwards but not by an attraction of the objects downwards.

⁴ The lines of motion of objects at different places are strictly parallel in an accelerated system, but are radial, that is, converging towards the center of gravitation, in a gravitational field. For this reason a large extent of the latter can not be equated to the former. In a small part of a gravitational field, however, those lines may be considered as being parallel.

The ball on the cord resists the accelerating pull upwards, thereby stretching the cord; the ball's inertial mass measures the tension of the cord. Or the ball tends toward the floor owing to gravitation, thereby stretching the cord; the ball's gravitational mass measures the tension of the cord. The two measurements determine the same effect. This illustration shows the importance of the law of the equality of gravitational mass and inertial mass in the study of gravitation. The effects of acceleration produced by a force at our command are examined and the results obtained are applied for determining the qualities of a gravitational field. Herein lies the physical significance of that law.

DETERMINATION OF THE QUALITIES OF A GRAVITATIONAL FIELD

The space and time factors of a process in a system may be given. They can then be determined, in a purely mathematical way, for an observer in another system which is in accelerated motion relative to the first system. By reason of the equivalence principle the second system is replaceable by a gravitational field. The qualities of the latter can thus be established mathematically. The following example makes this clear. The path of a body moving through a Galilean or inertial system, *i.e.*, one free from gravitation, is a straight line. What shape has it for an observer in a gravitational field? We return to our imaginary experiment. A bullet shot off in the interstellar space enters the physicist's room through a vertical wall and flies out through the opposite wall. For an observer outside of the room the bullet's path is a straight line throughout. For the physicist, however, it is a straight horizontal line when the room is at rest, a straight oblique line when the room moves uniformly upwards, and a curved line, a parabola, when the room is in accelerated motion upwards. In

the third case we may consider the room to be in a gravitational field. A quality of the latter is thus determined: what is a straight line in a Galilean system is a curved line in a gravitational field.

This gives us an idea of the mathematical complications in the study of gravitation. In an accelerated system or a gravitational field we can not construct a Cartesian coordinate frame of straight lines. The straight line loses its meaning there. The Euclidean geometry, being based upon the conception of the straight line, becomes inapplicable in an accelerated system, necessitating the use of another highly intricate geometry. Still more difficult is the mathematics required for systems in rotation, which is also a form of acceleration.

According to the special relativity theory a tangential length on a rotating disc is shortened, more when it is nearer the periphery than when it is nearer the center, while a radial length has the same value as when the disc is at rest. A clock nearer the periphery has on the rotating disc a slower rate than an equal clock nearer the center. The comparison of lengths of space and the correlation of intervals of time are therefore impossible in a rotating system. A length and an interval are here indeterminable, since they vary from place to place. In a rotating or an accelerated system, as can be shown, a square can not be constructed, the ratio between the periphery and diameter of a circle is not the well-known number π , and the Pythagorean axiom does not hold true. This means that the Euclidean geometry is useless in an accelerated system. To describe here the physical processes a method is needed in which the values of lengths and intervals can be dispensed with. Such a method is given through Gaussian coordinates.

A Gaussian system of coordinates consists of two series of lines curved arbitrarily, the lines of one series not

intersecting each other but intersecting those of the other series. Each line is represented by a number. A point is defined as the intersection of two curves and is thus determined by two numbers. This refers to a plane surface, *i.e.*, to a continuum of two variables. But the same method is applicable also to a continuum of more than two variables. The continuum figuring in physics has four variables, three relating to space and one to time. A point in it is determined by four definite arbitrary numbers which are its four Gaussian coordinates. These offer the advantage that they indicate coincidences of points and thus furnish for physical research a determinative factor which is independent of the system where the investigation takes place. A coincidence of two or more points is the only observable reality remaining the same in all systems, in one influenced by gravitation the same as in one free from it. In our space-time continuum a coincidence of points is given when they have in common one set of four Gaussian coordinates.

We see now that the previous enunciation of the general principle is inadequate. The term "system" used there and the term "motion" everywhere imply straight lines, lengths and intervals. These concepts are indeterminable in a gravitational field. Hence they should not be used in enunciating the principle. It becomes exact when stated as follows: "All Gaussian coordinate systems are equivalent for formulating the laws of nature."

The Gaussian coordinates of the space-time continuum are brought into relation to measurements of lengths and intervals through a roundabout mathematical way. It can be pursued only by the most able mathematicians. It leads to a general law of gravitation. This new law differs from the Newtonian law and embraces it in the first approximation, that is, when the mathematical cal-

culation is not carried too far. Herein lies a notable confirmation of the general relativity theory.

MISLEADING PHRASES OF, AND FANCIFUL IDEAS INJECTED INTO, THE RELATIVITY THEORY

A great authority remarked that "a single man, Einstein, destroyed confidence in the evidence of the Euclidean geometry," and another one stated that "the whole edifice of the Euclidean geometry is tottering." To such inadvertent utterances is due the widespread notion that Euclidean geometry has been overthrown. This is a fallacy. That geometry is not invalidated in the least, but only inapplicable in a gravitational field. A length is here unmeasurable and a straight line untestable. A light ray, the only standard for a straight line, is bent in a gravitational field. This follows from our imaginary experiment. The bullet shot through the accelerated room may be replaced by a light ray. The latter describes a parabola just as the former does. A non-Euclidean geometry, *i.e.*, one not founded upon the conception of the straight line, is therefore needed in the study of gravitational fields. This no-wise implies invalidity of the Euclidean geometry.

The quality of curvature was ascribed to the space in a gravitational field in order to explain why a light ray is bent and consequently Euclidean geometry inadequate in such a system. This idea was an unnecessary and infelicitous appendage to the relativity theory. It has caused great confusion and has involved the theory in mystery. The current phrase, "space is curved," is meaningless. Moreover, it has not been disproved that there is in the universe vastly more space free from gravitation than space influenced by it. A light ray has not been proved to be curved in the former. Now the only criterion for "space curvature" is the bending of a

light ray. Hence space is vastly more often "straight" than "curved," whatever this may mean. The deviation of a light ray in a gravitational field is readily explained without "space curvature."

The deflection of light through gravitation does not justify the claim that a light ray traveling through the universe may describe a circle and return to its origin, and the antipodes on the earth may see the opposite sides of a star at the same time. This could be the case only if all the innumerable gravitational fields traversed by a light ray deflected it invariably to the same side. Such a contingency is unthinkable. A ray will rather pass as many fields bending it to one side as fields deflecting it to another or to the opposite side. It will, therefore, not describe a circle but an irregularly curved line whose average course is straight. The notion that the path of a light ray in the universe may be a complete circle belongs to the fanciful ideas injected into the relativity theory.⁵

VERIFICATION OF THE RELATIVITY THEORY

Both the special relativity theory, treated elsewhere by the writer (see note No. 1), and the general one are confirmed by experience. Deductions from the former are corroborated by two astronomical observations, namely, the apparent displacement of the stars or aberration and the Doppler principle and by various electromagnetic and optical experiments. Similarly, inferences from the general theory are verified by experience, by observation. There are three such inferences, to wit, the devia-

⁵ See the writer's article, "Fanciful Ideas Injected into the Relativity Theory" (pp. 39-40), published in the *Am. Math. Monthly* for January, 1932, and obtainable from him as a reprint.

tion of light passing the sun's gravitational field, the anomaly of the planet Mercury, and the displacement of the spectral lines in the spectrum of sidereal light. It would unduly extend this essay to discuss all these interesting subjects at full length. They are enlarged upon and illustrated in a book, to be published later, of which this essay is an extract. In the latter it must suffice merely to mention all observational and experimental facts which support the special relativity theory and the general one.⁶

CONCLUDING REMARK

It is due largely to the use of the terms "fourth dimension" and "space curvature," mystical and meaningless in ordinary language, and to the injection of fanciful ideas into the relativity theory that it is so little understood. All these perplexities can be avoided in interpreting the theory. If it is not obscured and mystified through them, it can be made quite intelligible to the educated layman.

⁶ The unitary field theory has but little connection with the general relativity theory proper and is therefore out of the scope of this essay. The union of gravitation and electromagnetism forms the essence of the field theory but hardly comes into consideration in the general relativity theory. The notion of curvature infused into the conception of the "space-time continuum" has mystified and obscured this term. Yet there is nothing mysterious and difficult about it. Space and time in the new physics are united in a "space-time continuum." This merely means that both must be considered in describing a physical event so that it is fully determined only when the time variable is given together with the three space variables. Time is distinct from space, even in physics, and is not intermixed with it in any mysterious manner. Fancifulists tell us that gravitation has been replaced by "space-time curving around the sun." It is such meaningless abracadabra that has produced the prevailing confusion about the conception of the "space-time continuum" in physics.

INTERNATIONAL RADIO TUNING AT LONG RANGE

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ALTHOUGH radio broadcasting is only in its first decade of service, yet it is now well known to the general listener that a radio receiving instrument can not deliver speech or music until it has been tuned to the particular radio transmitting station that is "putting its program on the air." This means that each and every transmitting station has its allotted tone or electrical pitch, on which it is licensed to reach its listeners in the far beyond. Since there are many radio stations operating simultaneously, these precious radio channels through the ether lie close together in successive orders of pitch, and each station must keep faithfully to its assigned tone. It is as though each one of the 88 keys of a piano could somehow be used for audible signalling by an operator, independently of and without confusion from all the other 87. If, however, the pitch of his note altered seriously during operation, say by flattening, he would probably be brought into interference with the operator working on the note next below. The electrical pitch of a radio station is so high that it far exceeds the limits of audibility; yet it must not be allowed to flatten or sharpen beyond a very small range or it will interfere with the next neighboring pitch of some other station, which may happen to be far away. Nothing is more annoying to a radio sending station that is keeping true pitch than to find some other station invading its channel and confusing its program. To keep the radio peace, radio pitch must first be kept.

To facilitate the maintenance of the pitch or "carrier-wave frequency" of a radio station, electrical instruments,

called frequency meters, may be used, with the aid of which the station operator can assure himself from time to time that he is on tune. Occasionally, of course, such an instrument may become defective without the operator becoming aware of it, and then it is a case of "*Quis custodiet ipsos custodes?*" As a safeguard, it is not unusual for a standardizing electrical laboratory, such as the National Bureau of Standards at Washington, D. C., to broadcast, at certain announced times, a carefully tested and specified electrical pitch, so that stations prepared for the event may compare their frequency meters with the signal. In that way, small defects in the indications of such meters may be noted, far away from the station sending out standard pitch.

There is an international society called, in the English language, "The International Union of Scientific Radio"; but more generally known in Europe under its French title, "Union Radio-Scientifique Internationale," usually referred to by its initials URSI. The URSI investigates the science of radio communication, and has appointed several international standing committees to study different aspects of this wonderful subject. Committee No. 1, on "Standards," is interested in radio standards generally, and among them, in standard frequencies, their emission, measurement and intercomparison. This committee has recently issued a very interesting report on some frequency-emission tests made last June at the British National Physical Laboratory (usually abbreviated to NPL)—in Teddington on the Thames near London.

At the NPL, there was a specially constructed tuning fork, electrically driven, so as to be kept in action steadily for a long period, under carefully controlled air pressure and temperature. The pitch, or vibration frequency, of this fork was maintained very nearly constant at one thousand (1,000.00) to-and-fro vibrations, or cycles, per second. As this is a readily audible frequency in sound waves, and C², the note C on the second line above the treble clef, corresponds, on the scientific musical scale, to 1,024 cycles per second, the fork would emit a musical note of pitch slightly below C².

Many electric frequency meters depend upon building up successive octaves or multiples on a basic frequency of 1,000; so that if this basic frequency can be accurately established, correct radio frequencies of far higher pitch can be more readily assured. The object of the broadcasting tests was, therefore, to enable as many European stations as might be interested, to compare simultaneously their local 1,000-pitch forks with the standard fork in the laboratory at Teddington.

At the previously announced hour, which was actually midnight Greenwich civil time, *i.e.*, world time, the standard fork was connected, electrically, by underground wires to Broadcasting House, London, whence the standard frequency of 1,000 cycles per second was relayed on, again by wire, to a radio station in central England, at Daventry, about 125 kilometers northwest of Teddington. Daventry has Roman remains that show it must have been an established settlement in the days of that empire. It was also the headquarters of Charles I, in 1645, just before his defeat at the battle of Naseby. The Daventry radio station employs a carrier-wave frequency of 193,000 cycles per second. Since the highest pitch audible to the human ear is about 16,000 cycles per second, it is evident

that the Daventry pure electrical note, if picked up by a receiving loud speaker, would produce no sound; but by superposing on it the "modulation frequency" of 1,000, so as to cause the high electric pitch to wax and wane 1,000 times per second, suitably tuned and connected loud speakers all over Europe could be made to emit the note of nearly C² pitch.

Observations of the Daventry 1,000 modulation note were made in Berlin, Paris, Warsaw, Italy, Denmark and Sweden, besides in various English stations, according to the URSI report. The frequencies measured at these foreign stations, in terms of their own standards, as subsequently reported by them, varied between the limits of 1,000.0002 and 999.9997 cycles per second, a total range of 0.0005, or one part in two millions. The report indicates that, judging from the experience of this and similar tests, it should be feasible to determine and maintain a standard frequency, of this order, to a precision of one part in ten millions. This degree of precision, while very satisfactory from a scientific point of view, is considerably in excess of practical radio requirements at the present time.

The NPL standard fork had itself been measured and adjusted in its frequency, by daily astronomical time signals, and a first-class standard laboratory clock.

Two inferences disclose themselves from a perusal of the report; one physical and the other philosophical:—namely, first, that these frequencies of carrier wave and of modulation, emitted from the Daventry radio station in various directions, remained constant up to a range of 1,000 kilometers, to within a measured precision of at least one per million. This constant-frequency property of traveling radio waves is generally accepted; but, possibly, had not previously been submitted to so severe a test. Second, during the continuation of the tests, which actually

occupied only a few minutes, the effect of the various wire and wireless connections was such that the standard fork in the NPL laboratory was virtually transported into each and all of the various receiving laboratories—in the sense that the actions there locally produced were equivalent to those that might have been produced, if the fork had been instantly transported across the intervening surface of the globe.

So long as the various nations are able to maintain their standard radio frequencies to within a few parts in ten millions, it is evident that peace and amity may be expected to enfold them. Every radio link is a bond of good-will. As radio science develops, under the auspices of the URSI, it may be hopefully anticipated that the same precise exchange of frequencies will gradually extend from one to all the continents.

SALIENT THEOREMS OF THE THEORY OF GROUPS AND THEIR HISTORY

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AMONG the 1932 theorems relating to the foundations of group theory is the one which asserts that the quaternion group is the only finite non-commutative group containing a set of generating elements which includes the product of every pair of distinct elements thereof without involving all the elements of the group generated by it. This theorem exhibits, in particular, the extent of the probable misunderstanding as regards finite non-commutative groups resulting from the common statement that one of the conditions that a set of operators constitutes a group is that it involves the product of every pair thereof. A rule equivalent to the formula that the number of pairs of n distinct elements is $n(n-1)/2$ was given by Ammonius, the founder of the new Platonic school, but it has often been erroneously credited to Boethius, who lived about 275 years later.¹

It is a somewhat singular fact that such an elementary theorem has not yet been found in the earlier literature. In particular, it does not appear in Euclid's "Elements," which includes so many of the results found by earlier in-

vestigators. Such negative results throw much light on the history of the intellectual development of the human race and on the weak points of the mathematics of early civilizations. While no expression for the number of pairs that can be formed with n distinct elements seems to appear in the mathematical literature preceding the Christian era there are many evidences therein of the consideration of pairs. For instance, Euclid's "Elements" contain a rule which is equivalent to the formula $4ab + (a-b)^2 = (a+b)^2$, where a and b represent positive numbers and a is assumed to exceed b .

It has not been sufficiently emphasized in the histories of mathematics that the Greek geometric interpretation of the rule which is equivalent to the formula $(a-b)^2 = a^2 - 2ab + b^2$ is of fundamental importance in the history of negative numbers, since it gave rise to the rule that a subtracted number multiplied by a subtracted number gives an added number, and a subtracted number multiplied by an added number gives a subtracted number. This rule is found in the "Arithmetica" of Diophantus and gave rise later to the modern rules relating to the multiplication

¹ Cf. D. E. Smith, "History of Mathematics," Vol. 2 (1925), page 524.

of positive and negative numbers. The addition and the subtraction of positive and negative numbers were clearly understood long before the operations of multiplication and division relating thereto were explained in a satisfactory manner.

The development of the theory of negative numbers was doubtless influenced by the observation that they may represent the inverses of the corresponding positive numbers such as debts when the positive numbers represent credits, or distances in the opposite direction from those represented by the positive numbers. The available evidences seem to point to the fact that the most potent influence in the introduction of negative numbers was the development of a calculus of binomials on the part of the ancient Greeks, especially in the form of differences between two positive numbers. This calculus appears in Euclid's "Elements," and it became widely and favorably known as a result thereof. The development of negative numbers is an important element of the history of group theory, since the totality of numbers could not be regarded as a group with respect to addition until negative numbers and a zero were regarded as a part of their domain.

An important element of the definition of a group which has not received much attention on the part of writers on this subject is the fact that only two elements are supposed to be combined at the same time therein. If more than two elements of a group are combined it is assumed that the result is obtained by combining successively two of them or by combining the result thus obtained with another element of the set. Such an operation as combining n elements and also multiplying their ordinary product by n is not considered in group theory for the cases when $n > 2$. Hence it results that the question of pairs of elements is fundamental in this subject

even if the number of such pairs is of secondary importance therein.

The fundamental theorem of algebra is equivalent to the statement that an algebraic equation of degree n has exactly n roots. In group theory only binomial equations of the form $x^n - 1 = 0$ are considered and such an equation has exactly n roots within a group of order n . There is only one such group when and only when n is not divisible by the square of a prime number and also none of its prime factors diminished by unity is divisible by another such factor. In all other cases it has more than n roots within the groups of order n . It is especially important to note in this connection that whenever n divides the order of a group, then this equation has always a multiple of n roots within this group, according to a theorem proved by G. Frobenius in 1895 and known by his name. It is not always possible to construct a group for which there exists an arbitrary multiple of such roots.

The development of group theory during the last forty years is analogous to the development of entire mathematics during the early part of the nineteenth century. The enumeration of all the possible groups of a given order and the recent determination of all the orders for which a given small number of groups exist are comparable with the work of the combinatorial school of Germany founded by C. F. Hindenburg (1741-1808), while the theory of linear groups and group representation may be compared with the developments of A. L. Cauchy and N. H. Abel relating to the convergence of infinite series. The former led to some useful results, but the complexity encountered turned investigators into other fields. Elegance and simplicity of results have always exerted a powerful influence on the mathematical investigator. The almost 300 distinct groups of order 64, for instance, can scarcely be supposed to

appeal to those who wish to use group theory as a tool for investigating other subjects. On the other hand, the theory of the representation of groups has recently been successfully employed in physics by H. Weyl, E. Wigner, B. L. van der Waerden and others, and promises to become a substantial part of mathematical physics, even if it has been referred to by some of the workers in this field as a pest which should be gradually eliminated.

E. Galois and L. Sylow contributed towards the development of a salient theorem which is now commonly known by the name of the latter and asserts that every group of finite order contains at least one subgroup whose order is the highest power of a prime number which divides the order of the group. The former of these two investigators died before reaching the age of 21 and is the only man who secured at such an early age a position among the 25 leading mathematicians of all times. On the contrary, the latter developed slowly and did not secure a university professorship until he was about 66 years old. E. Galois stated without proof that if the order of a group is divisible by a prime number, then it contains a subgroup whose order is this prime. A proof of this theorem was published by A. L. Cauchy in his noted "Exercises" (Vol. 3 (1844), page 250). The article in which Sylow's theorem first appeared (1872) contains also the theorem that a group whose order is of the form p^m , p being a prime number, contains an invariant subgroup of order p and hence it contains at least $p - 1$ invariant operators of this order. This theorem has been very fruitful.

It is not our object to give here an extensive list of salient theorems of group theory, since many of them involve points which are of little interest to the general reader. A list of 217 such theorems appears in A. Speiser's "Theorie der Gruppen von endlicher

Ordnung," second edition, 1927. Our object is to give here a few instances of the nature of the questions considered in this field of mathematical activity. This may be justified by the fact that a growing general interest in this field may be supposed to result from the recent uses made of group theory in mathematical physics by H. Weyl and others, and that this subject has recently been recognized as belonging to elementary mathematics in the second part (1932) of Vol. 1, "Enciclopedia delle matematiche elementari." This recognition is the more interesting, since the Italians have made comparatively few contributions to this field and give generous references to contributions along this line by American writers. In no other field are such contributions more outstanding.

The difficulties of the student of modern mathematics are greatly increased by the lack of uniformity in the use of terms and by the liberty exercised by some writers of wide reputation to deviate from well-established usage. As an illustration we cite here H. Weber's use of the term metacyclic for solvable. If writers who have not yet an established reputation make such digressions it is commonly regarded as an error, but writers of renown are usually granted by the mathematical public licenses which unduly tax the younger workers in the same fields. H. Poincaré could say without refutation "The theory of groups is, so to say, entire mathematics divested of its matter and reduced to pure form" ("Acta Mathematica," Vol. 38, 1921, p. 145). A somewhat more critical attitude would probably tend to lessen the burden of those to whom future progress will be confided. The modern formal mathematics is obviously not now confined to group theory, as this term is commonly understood.

The concept of cyclic group is as old as that of the circle, and hence it is pre-

historic. The fact that the number of the hours of the day may be regarded as a modulus with respect to the addition of time, and hence that the numbers of these hours constitute a cyclic group with respect to addition, was realized by the ancient Babylonians and the ancient Egyptians, who employed early a day of 24 hours. Sometimes two moduli were used for the day and the night respectively, and various other divisions were employed. In fact, in some countries two moduli, each equal to 12, are still in use. The fact that all the vectors of the plane, and also those of space, constitute a group with respect to addition enters into the experience of our daily life and is fundamental in elementary geometry. While the concept of cyclic group is very ancient, the properties of this group, such as the number of its generators, now known as the totient or the Euler ϕ -function of its order, do not seem to have been explicitly noted before the eighteenth century.

The concept of non-cyclic group is more difficult to trace far into the past literature, and comparatively little progress has been made along this line. The simplest example of such a group is the four-group, which appears explicitly as a permutation group in the works of J. L. Lagrange, but is probably much older. It contains a set of three generating elements, each of order 2, which includes the product of every distinct pair of them, and hence it also illustrates the danger of misunderstanding resulting from the statement that a set

of permutations constitutes a group if it involves the product of every pair thereof. Josiah Royce called attention to the fact that a certain set of three logical entities of the Boolean calculus define this group, which is also known as the axial group, or the anharmonic ratio group.²

Arithmetic and geometric series are among the most ancient concepts of mathematics, as they appear already in the ancient Egyptian mathematical papyrus written by Ahmes. It has recently been noted that an arithmetic progression extended infinitely in both directions constitutes a group when and only when it involves the sum of at least one pair of its terms. Similarly, a geometric progression thus extended constitutes a group if and only if it involves the product of at least one pair of its terms. The very elementary character of these facts would seem to justify the effort to find earlier explicit statements thereof, but in the history of science as well as in the development of science it is observation and experiment that give a definite yes or a definite no to our hypotheses. While group theory is a comparatively young subject its history presents many unsettled questions and points to the almost insurmountable difficulties involved in securing a satisfactory general history of the entire field of mathematics. The efforts along this line are, however, laudable, since they tend to exhibit inspiring advances which appear to be of permanent value.

² Cf. *Journal of Philosophy, Psychology, and Scientific Methods*, Vol. 10, p. 619, 1913.

ENEMIES OF SOCIETY¹

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THE history of our race may be instructively considered in terms of a gradually expanding freedom. Slowly and painfully, in the course of many centuries of struggle, we have cast off the chains of slavery, and to a great degree we have overwhelmed the tyranny of government. Within reasonable limits we have achieved liberty of speech and of printing. But these were achievements in civil or political liberation. By applying knowledge of physical and chemical sciences we have further freed ourselves from exacting restrictions. Thus the limitations which seasonal changes impose we have escaped by devices for heating and refrigeration; we have pushed far away the confines of space and time by rapid transportation of goods and people on land and in the air, and by the flashing of information in seconds from the remotest corners of the earth; by means of artificial illumination we have abolished the terrors of darkness; and through the methods of orderly research we have learned the nature of mysterious events in the heavens and on the earth that from earliest times have held the minds of men in fear of dire disasters.

As members of the medical profession we are justified in regarding with pride the rôle which our profession has played in the process of setting humanity free. In performing this service to humanity I would emphasize the point that medical methods of inquiry that have been used by investigators have used the same methods as investigators in physics and chemistry. They have studied biological phenomena

as they occur in nature, they have drawn inferences concerning them, they have tested these inferences by experiment, and thus by patient, ingenious and critical study they have learned the regular sequence of events, "the rules of the game." And just as this scientific method has transformed the physical world, giving us means of electrical heating and cooling, the automobile, the airplane, the telephone, wireless communication and animated speaking records, so likewise the method has helped to transform the social world by its conquest of disease. Let us consider for a few moments the thraldom of plagues and pestilences under which our ancestors suffered, and we shall be better able to estimate the momentous services of medicine in establishing the relative security of our present civilization.

Again and again, after devastating Asia and Africa, the bubonic plague swept into Europe. Many vivid descriptions of the havoc it wrought have come down to us. One epidemic in the fourteenth century is said to have caused the death of over 60 millions of human beings. In that epidemic Genoa lost 40,000, Naples 60,000, Siena 80,000 and Sicily and Apulia more than 500,000 inhabitants. The city of Trapani was completely depopulated—all died—and her silent walls and empty dwellings were alone left to tell the tale. The dead were dumped pell-mell into huge pits, hastily dug for the purpose, and putrefying bodies lay neglected everywhere in the houses and the streets. During later centuries scattered outbreaks of the plague in various European countries were accompanied by

¹ An address read at the annual meeting of the New York Academy of Medicine on November 3, 1932.

similar scenes. Pepys in his diary tells of what he saw at the "great pit of the churchyard at Aldgate" as one dead-cart after another brought its load, "sixteen or seventeen bodies, some wrapt in linen sheets, some in rugs, some little other than naked, or so loose that what covering they had fell from them in the shooting out of the cart"—"huddled together into the common grave—rich and poor together." "Now people fall as thick as the leaves in autumn when they are shaken by a mighty wind," reported Thomas Vincent, an eye witness. "Now there is dismal solitude in London streets. . . . Now shops are shut in, people rare and very few that walk about, and a deep silence in every place. . . . If any voice be heard it is the groans of dying persons breathing forth their last. . . . Never did so many husbands and wives die together; never did so many parents carry their children with them to the grave, and go together into the same house under earth who had lived together in the same house upon it. Now the nights are too short to bury the dead; the whole day, though at so great a length (it was August), is hardly sufficient to light the dead that fall thereon into their graves." The mysterious and appalling disaster wrought wide-spread demoralization among the people: some, overcome by terror, fled from their friends, their homes, their dearest relatives; others gave themselves up to the wildest debauchery—"eat, drink and be merry," they said, "for to-morrow we die." Such was the plague during hundreds of years of European history.

It should not be forgotten that the plague has not disappeared. An epidemic starting in China spread over the world in 1894, and without modern protective agencies would probably have attained medieval proportions. In India alone, during the year 1905, the number of recorded deaths from plague was

more than 1,040,000. Two years later our own country was invaded, and serious conditions might have developed if stern measures had not been taken to protect our population. These measures, as you well know, were based on careful scientific studies which had revealed the natural sequence of events. It was proved that the bacillus pestis is spread among rats by fleas and can be transferred by these insects from rats to monkeys. The inference was clear. To protect men from these dangerous flea bites the rodent carriers of the fleas must be destroyed. Those were the rules of the disease as demonstrated by tested experience. Now, in accordance with these rules, rats are trapped and killed, rookeries and vermin-breeding hovels are torn down, and victims already infected are isolated, so that they shall not be the cause of further infection. Wherever it has been possible to apply the rules, seriously threatening epidemics of the plague have been stopped so that mankind is now largely freed from the terror of the Black Death.

May I be permitted to mention in some detail another extension of human freedom due to our profession—the growing freedom from the disease diphtheria. Death from this disease was formerly frightful both for the victim and for the attendants, because the membrane in the larynx commonly caused strangulation. Indeed, the Italian name for diphtheria was "garottillo," the strangler. Listen to Rousseau's classic description of the way in which diphtheria used to kill 50 per cent. of those attacked:

The difficulty of respiration increases in severity. Every hour, or every two or three hours, a suffocative fit comes on. The suffocative attacks follow one another more rapidly and become more and more violent. From time to time the infant, in a state of excitement which it is impossible to describe, suddenly sits up, seizes the bed curtains and tears them with convulsive frenzy; he throws himself on the neck of his mother or on those

about him, embracing them and trying to clutch whatever he can as something to hold by. At other times it is against himself that he directs his impotent efforts, grasping violently the front of his neck, as if to tear out from it that which is suffocating him. The puffy, purple face and the haggard, sparkling eyes express the most painful anxiety and the most profound terror; the exhausted child then falls into a sort of stupor, during which respiration is difficult and hissing. The face and lips are pale, and the eyes sunken. At last, after a supreme effort to breathe, the agonies of death begin and the struggle ends.

Such pathetic and distressing scenes we have not witnessed for nearly four decades. By carefully conducted experiments on guinea pigs, rabbits, goats and horses, the rules of the disease were learned, *i.e.*, that it is caused by a bacterial toxin, that the body produces a defensive antitoxin, and that by use of an antitoxin developed artificially in the blood of the horse the natural defences of the patient can be promptly and overwhelmingly reinforced. By employing this tested knowledge—by obeying the natural rules which critical experience has discovered—the death rate was reduced in 19 of the largest cities of the world from about 80 per 100,000, in 1894, to 17, in 1907, a short period of 13 years. When antitoxin is used as soon as the disease can be diagnosed the mortality is almost nil. And now, best of all, by active immunization whole populations can be effectively protected from attacks.

I have not the time, and it is not necessary before this audience, to detail other triumphs of the application of scientific methods to medical problems. It will serve my present purpose, however, to refer to a few of them in a cursory survey.

By application of the experimental method the rules of surgical sepsis were learned and the rules for avoiding sepsis were discovered and developed. Thus was made possible the beneficent services of modern surgery—in the removal of tumors, the abolition of neuralgic and

other pains, the repair of injured parts, the exclusion of dangerous infections.

By learning through experiments the rules of the diseases medical investigators have shown how yellow fever and typhoid fever, which formerly afflicted vast populations, can be controlled and rendered insignificant.

By learning the rules of the diseases the experimenters have been able to reduce the death rate of hydrophobia from about 14 per cent. of persons bitten to less than 1 per cent.; to reduce both the mortality and the damaging consequences of the epidemic form of cerebro-spinal meningitis; to reduce the death rate from tuberculosis to about one fourth what it was fifty years ago.

By a long series of experimental inquiries the rules of the disease, diabetes, have been largely learned, and in accord with these rules there has been discovered within the past ten years a method of treatment which has freed hundreds of thousands of diabetic patients from the pangs of starvation, prolonged the life and usefulness of adult victims and given to diabetic children assurance of continued existence.

Through another series of experimental researches, the mode of dealing with anemia was suggested, and in consequence a certainly fatal human disorder, pernicious anemia, has been brought under control.

Many more examples might be given to show how medical and biological investigators, using the same general methods of inquiry as are used by chemical and physical investigators, have disclosed the secrets of natural processes and thereby have made for humanity if not a new heaven, at least a new earth. The lesson of these triumphs is clear. If we learn nature's rules, the regular and routine sequence of events, and then play the game of our relation to natural events in accordance with those rules, we can move onward to larger, more

complete control of these events. And just as we secure such control and use it, we leave uncertainty, we no longer see as through a glass darkly but face to face, and by such knowledge more and more are we made free. To medical investigators human society owes an incalculable debt of gratitude for relief from distressing pain, from the terrors and abominations of disease and from early death.

If you grant all that I have said up to this point, and I have tried to rest my case on well-authenticated facts, you can readily understand why it is that the training for the profession of medicine requires a longer time than the training for any other profession. The prospective physician, learning to understand the human body, is confronted with the most complicated system of co-operating parts that is to be found anywhere; he must learn the normal structure and workings of those parts singly and in relation to one another, for he needs that knowledge in order to have a basis for the recognition of disease. After he has met that reasonable requirement he must be educated in regard to all the more common diseases so that he can identify them, and he must become acquainted with the numerous and intricate rules of bodily order and disorder which he must later teach and enforce in order to maintain personal and social health; he must know the peculiar values of the varied forms of remedial agents and procedures so that he may apply the treatment most helpful to each patient; in emergencies he must be able to recognize promptly the existing conditions, for failure to do so may result in death. When, after at least six years of intensive professional study and one or two years of intensive observation and care of patients in hospitals, he is at the end of his formal training, he is ready to be a reliable servant of society in the treat-

ment and prevention of disease among its members.

All these considerations are so familiar to this audience that I have hesitated to recite them to you. And yet if such stern and rigorous discipline is regarded by us as the prerequisite for certified expertness in medical practice, what shall we say of those who scorn the need for such discipline, who ridicule the evidence which painful human experience presents in overwhelming volume, who rush in as experts in the cure of disease when they have not learned the elements of the normal or the pathological processes with which they must deal? I submit that such persons are properly designated as enemies of society. I propose to consider with you some of their characteristics and to discuss the social dangers of their attempts to practice medicine.

In the first place, we must realize that our profession has undergone a long process of evolution. Magicians and medicine-men constituted the earliest professional class in primitive society. For thousands of years they made use of many varieties of incantations, charms, amulets, elixirs and decoctions, as well as prayers, music and the laying on of hands. Only gradually have rational medical knowledge and treatment risen out of this foggy morass of mysticism, and only during the past eighty years has the seal of experimental proof been placed on medical inferences. During all this recent history of the race, at every stage, representatives of the earlier fantastic and superstitious period of medical practice have appeared. At the time of Clowes, Paré, Vesalius and Linaere, in the sixteenth century, quackery was rampant, and was practiced, as a contemporary report has it, by "tinkers, tooth-drawers, peddlers, ostlers, carters, porters, horse-gelders and horse-leeches, idiots, apple-squiers, broom-men, bawds, witches, conjurers,

sooth-sayers and sow-gelders, rogues, rat-catchers, renegades and proctors of spittle houses." Two centuries later, when Monro, Boerhaave, the Hunters, Withering, Jenner and physicians of like character stood out as builders of the rising edifice of medicine, they were surrounded by successors of the primitive magicians—astrologers and holy healers, who practiced on the sick in the ancient manner, selling anodyne necklaces to pregnant women, providing "celestial beds" for the cure of sterility (at £50 per single occupation!), lauding the virtues of magnetic tractors, making fortunes from proprietary medicines (one of which was composed of "egg shells, garden-snails, swines' cresses, soap, burdock seeds, hips and haws"), and employing the ancient artifice, "laying on of hands."

Again, two centuries later, at the present time, we find the same elements present among those who profess to care for the sick. On the one hand are they who represent the growing forces of medical knowledge which, as I have reminded you, have mitigated or abolished great pandemic diseases and brought the blessings of surgical skill so that human society now lives in a new sense of security. On the other hand are the modern representatives of sourcerers, mystics, vendors of panaceas and artists in the magic touch. Practitioners of Christian Science, chiropractors and naturopaths are to be found on all sides, using the historical methods of faith cure and manipulation. What is the basis on which they rest their methods?

Christian Science denies the existence of disease. "Disease is illusion," wrote Mrs. Eddy. "Man is never sick, for Mind is not sick and matter cannot be." . . . "Disease is always induced by a false sense mentally entertained, not destroyed. Disease is an image of thought externalized." Thus with the dash of a pen-stroke the achievements of the medical profession in saving and

protecting mankind from devastating pestilences is lightly dismissed as an absurdity.

"Chiropractic" is built on a slight modification of the ideas which originally supported osteopathy; now, because osteopathy has broadened its methods and requires more exacting standards than formerly, "chiropractic," with its brief preparation and low requirements, is usurping its place. According to chiropractic theory disease is due to partial displacement of vertebrae which pinch spinal nerves passing between them and which thereby interfere with the flow of vital energy to the body tissues. As B. J. Palmer, head of the original Palmer School of Chiropractic, testified in court, "Chiropractically speaking, disease is simply a register as to the amount or excess of current that an organ receives at the end of a nerve." For instance: "diarrhea shows too much force going to the bowels, particularly to the rectum. In constipation there isn't enough force going. It is simply a register of force at the same place in two different quantities, both being regulated by subluxation in the spine." . . . "Too much function or not enough function is the only classification you can put on disease" . . . "melancholia, not enough function, in the maniac too much" . . . "in the case of the kidneys, diabetes too much, Bright's disease not enough." "Do you recognize reflex action?" asked the lawyer. "Absolutely no," was Palmer's answer. "Do you recognize the sympathetic nervous system?" "No, we recognize only a direct nervous system and the direct flow of current." By manipulation the chiropractor is supposed to correct the mal-positions of the vertebrae—not instantaneously, but by steps—and as the bones are gradually restored to their normal places the disease which they have caused is modified and finally disappears. Such are the ridiculous claims. And there are about 16,000 chiroprac-

tors in the United States supporting these claims—and incidentally themselves!

The naturopaths and their ilk, unlike the chiropractors, employ many healing agents, but rule out drugs and surgery. According to the leader of the sect, only the naturopath knows the right combination of these agents. They include *thalamotherapy*, treatment of disease by light through colored lenses that affects the viscera through the thalamus; *syntomotherapy*, treatment by means of vibrations which "equalize the circulation in the body"; *neuropathy*, simultaneous and intermittent manual pressure on one or more parts of the body to relieve nerves that are affected through muscular lesions, faulty nutrition or traumatic conditions; and *new field science*, removal of the cause of disease and the neutralization of toxic states by proper chemical combinations, as found in desiccated vegetation, herbs and cell salts. One naturopathic "cure" is known as the *Christos biological blood wash*, which consists of spraying water on various areas of the skin for some eight hours—really a prolonged shower bath!

The catalogue of the First National University of Naturopathy has this to say regarding entrance requirements, "Although a high school education is a great advantage in enabling the student to grasp the principles taught, this is not yet demanded." On completion of the course the student receives four diplomas, doctor of chiropractic, doctor of naturopathy, doctor of physiotherapy and master of physical culture. At another college, conducted in night courses, an insurance clerk was reported to be "professor of pathology," and among the candidates for the D.N. degree were a carpenter, a watchmaker, an ex-window washer, a telegraph messenger and a hod carrier. It is estimated that there are about 2,500 such healers in our cities.

All the representatives of these cults

set themselves up as practitioners of the art of healing and declare that they cure all kinds of illness. But what basis have they of knowing a disease when it is present? Christian Scientists are not required to know anything of the structures and workings of the body, its changes in pathology or the symptoms and signs of disorder—indeed, their doctrine renders all such knowledge unnecessary. Socially dangerous and socially controllable infections, such as smallpox, typhoid fever, septic sore throat, do not exist. They are delusions—the mere "image of thought externalized." Is it safe for society to trust its welfare to persons who act in accord with such absurd ideas? Is it proper to look with equanimity on "healers" who consider dysentery or diphtheria in an infant as being "a false sense mentally entertained," and then proceed to treat the condition by prayer? Such spurious "healers," posing as experts, speaking with impressiveness, but in fact abysmally ignorant of the whole range of knowledge which adequate treatment of the sick requires, are a menace to humanity.

Little more can be said for the chiropractors and the naturopaths. First of all, they are advocates of low standards of preparatory education. Instead, I claim, unusually high standards should be the prerequisite. The art of healing is the only professional activity which is practiced by ostensible experts in the absence of other experts. Unlike the doctor, the teacher engages in public activity and may be under surveillance of a superior; the engineer has his work tested by inspectors; the lawyer practices in open court confronted by an opposing lawyer and a judge. The doctor, on the contrary, closes the door as he enters a home and thereafter what he does receives no higher criticism than that permitted by the judgment of a layman. The organized medical profes-

sion, realizing these facts, has done all that it could to make certain, when a novice begins the practice of medicine, that he shall know from laboratory study the practical aspects of anatomy and physiology, pathology, bacteriology and other medical sciences, that he shall be able because of numerous contacts with patients in dispensaries and hospitals to recognize all common varieties of disease or make the proper analyses for their determination, and then that he shall be ready in the treatment which the shared experience of trained physicians has proved to be most effective. To that end, as I have already noted, the prospective doctor spends about eight years in professional study and hospital experience. Such training is requisite before he is prepared to undertake the intimate, the delicate and often the onerous responsibilities of practice. It is the longest and most expensive of all professional preparations.

Compare this preparation with that required for chiropractors, naturopaths, sanipractors and their kind. Courses in the basal sciences are eliminated. A high-school preparation is sufficient in the best schools, and mature age, business experience or any convenient achievement is a satisfactory equivalent. The students are allowed to go forth from these "colleges" or "national universities" with a minimal attendance—the common requirement is eighteen months, but one so-called "university" is a correspondence school and grants a diploma for \$127.50 after a course depending for its length on "individual ability." The schools are admittedly established on a business and not on a professional basis. The students are instructed not only in manipulative methods but in salesmanship. "We teach them the idea," the founder of chiropractic boasts, "and then we show them how to sell it!" Laboratory training in physiology, physiological chemistry, bac-

teriology, histology and pathology is, in practically all schools, wholly lacking. The subjects are either omitted or taught by didactic lectures or illustrated by quite inadequate apparatus. The teachers are in no sense competent; commonly they possess only the D.C. or Ph.C. (philosopher of chiropractic!) degree, and they are not paid salaries which permit them to satisfy scholarly interests, if they ever had any. They are not members of professional scientific societies. The clinics are not adequate for training in the diagnosis of even the most ordinary diseases. Indeed, as the catalogue of the leading chiropractic school once announced, "The chiropractor does not take the temperature, he never taps the chest or stethoscopically listens as in auscultation . . . he never looks at the tongue . . . in fact he makes no diagnosis or examination." All patients are considered from the sectarian point of view (according to chiropractic, diphtheria is due to subluxation of the sixth dorsal vertebra, scarlet fever the twelfth dorsal!) and the treatment is limited to the peculiar forms of manipulation. Naturally enough, representatives of these cults are frankly out of sympathy with the organized medical and public health interests established in the nation, the states and the large cities, and are openly antagonistic to many of the most universally recognized facts and procedures of civilized society—such as the bacterial cause of infections, the use of diphtheria antitoxin and antityphoid vaccination and the necessity of quarantine. No reliance is placed upon them by any agency responsible for the protection of the people against epidemic diseases, or against the dangers of food poisoning and bad sanitation. No signs of disinterested public service on their part are evident. No discoveries which have brought any benefit to humanity can be credited to them.

When we consider that the cults are

based on a theory of the nature of disease which is quite without any supporting evidence that has ever commended itself to critical judgment and which is wholly at variance with the well-proved facts of experimental and clinical observation; when we consider that the practitioners of these cults have no adequate scientific training, no trust in the methods which have freed mankind from vast and disastrous pestilences, no thorough discipline in the diagnosis of disease, and as a rule no versatility in their attack on disease but only the single method of projected thought or suggestion or vigorous handling of the body; when we know from court records that they have, for example, treated by such means diphtheria, peritonitis and bronchopneumonia; and when we realize that chances favor the practice of their methods on the most easily deceived and most credulous members of society, I believe that we are justified in regarding them as sources of danger, as actual enemies of society.

The question may properly be asked why these cults exist, why there are in our country nearly one fourth as many sectarian "healers" as there are practicing physicians. One reason, no doubt, is the present high standard of training for the practice of medicine. The cults afford a means of evading it. That standard was raised, however, because the organized medical profession, about thirty years ago, realized that there were many poor schools which were sending forth ill-prepared doctors and it set to work to close such schools and to put a premium on excellence. In consequence, the number of medical schools was reduced about half, and the remaining institutions were greatly improved in their methods of training physicians. Also the profession has supported the move to raise the state requirements for medical practice. We have still with us, however, the products of the earlier

time, physicians whose training was fundamentally inadequate and whose services to the sick in any complex situation are likely to be unsatisfactory. But even if the trained doctor were a man of much less ability, insight and understanding than he is to-day, could that possibly justify admitting to medical practice less well-trained doctors? No! We need higher standards rather than lower.

Another reason for the existence of cults, that involves the well-trained physician, is that he frankly admits the need for studying a possibly obscure case before expressing an opinion about it. Many patients interpret such caution as ignorance and suppose that quick decision means knowledge. The "healer," with his prompt and positive assertions and his limitless self-assurance, is thus given credit which is withheld from the doctor—quite possibly to the disaster of the patient. Still another reason is found in the growth—may I suggest overgrowth—of specialization in medicine, with its attendant transfer of patients from office to office and the consequent high costs. Moreover, there are members of the medical profession who have been tardy in appreciating the psychic element in illness. Furthermore, the fact must be recognized that, with respect to disease especially, human beings often believe in the potency of magic. The "healer" is looked upon as a greater magician than the careful, scientifically disciplined doctor. Finally, individuals report that they have been *cured* by the procedures employed, a *post-hoc-ergo-propter-hoc* inference which wholly overlooks the self-corrective devices of the body and which has been used to justify every absurd therapeutic agency ever conceived, from the beating of a tom-tom outside a tepee to the prescription of western fresh-air pills. Not one of these reasons is cogent for the tolerance in

our civilization of groups of medical pretenders—ignorant, untrained, often unprincipled, and always dangerous both for what they do and what they do not do for those who resort to them. In the main the organized cults are found only in Canada and the United States; the rest of the civilized world manages well without them. An enlightened society would see to it that its innocent members who require skilled attention because they are ill receive intelligent professional service and are not exploited by charlatans.

Another group of enemies of society are the antivaccinationists. They object to conforming to the rules which have been learned about smallpox and thereby they not only expose themselves to the dangers of that disease but also they try to establish conditions which would expose to its attacks innocent children, not old enough to exercise independent judgment. Like the Black Death, smallpox has been at times one of the great plagues. Highly variable, it smoulders in mild attacks for a time, and then, if conditions in the population are favorable, it may suddenly break out in a violent epidemic. In 1802 Admiral Berkeley reported in the House of Commons, "In this United Kingdom alone 45,000 persons die annually of the smallpox; but throughout the world what is it? Not a second is struck by the hand of time but a victim is sacrificed upon the altar of that most horrible of all disorders, the smallpox." As the historian, Macaulay, has recorded, "Smallpox was always present, filling the churchyard with corpses, tormenting with constant fear all whom it had not stricken, leaving on those whose lives it spared the hideous traces of its powers, turning the babe into a changeling at which the mother shuddered." Frederick William III, of Prussia, in a dispatch dated October 31, 1803, stated that 40,000 people succumbed annually

to smallpox in his kingdom. The French physician, De la Condamine, declared in 1754 that "one fourth of mankind was either killed by it or crippled or disfigured for life." So thoroughly infectious is the disease that it was reported by contemporaneous writers in the eighteenth century that as many as 80 to 90 per cent. of the population were marked as survivors of attacks of smallpox.

It is not generally known that in former times smallpox was essentially a disease of children, so much so that it was called "child pox." Then the adult population consisted largely of survivors of smallpox in childhood. In the small town of Kilmarnock, for example, there were nine epidemics of smallpox in the 31 years from 1728 to 1764. The total deaths from this disease were 622, and of these, 586 were deaths of children under six years of age; only 7 were more than ten years old.

It is not generally known that smallpox not only kills or disfigures and maims, but also destroys vision. The early records of the London Asylum for the Indigent Blind showed that two thirds of the inmates had lost their sight through smallpox. And according to Sir William Aitkin, 90 per cent. of the cases of blindness encountered in the bazaars of India are due to that disease.

Now what are the laws of that disease? Observation suggested that persons who had had an attack of cowpox did not contract smallpox. Jenner tested experimentally that idea and found evidence that it was correct. Then began vaccination with cowpox on a large scale. Human experience in all parts of the world has shown that a successful "take" protects against smallpox for a period varying on the average from 7 to 10 years, that when this immunity is exhausted a second "take" renews it, that persons twice successfully vaccinated are usually immune for

life, and that even when not fully immune, a vaccinated person who has an attack of smallpox suffers much less severely than a person who has not been vaccinated.

When the rules of this disease and protection against it are respected the results are striking. Careful statistics gathered in European countries clearly prove that those with most stringent vaccination laws suffer the least from smallpox, namely, Germany, Denmark, Sweden and Norway. In well-vaccinated Germany the mortality has been for years in the neighborhood of 1 person per 1,000,000 of the population. In England and Wales, where vaccination is generally but not universally practiced, the mortality has been about 20 persons per million per year. The experience of foreign countries has been duplicated in the United States. In Massachusetts, where there is a heterogeneous population of about 3,850,000, a fairly strict compulsory vaccination law prevails. In the ten years, 1919 to 1928, 408 cases of smallpox occurred. In the four states, Arizona, Utah, North Dakota and Minnesota, where compulsory vaccination is prohibited, the total population is almost the same as that of Massachusetts. During the same decade these states had 46,130 cases of smallpox, 113 times as many as Massachusetts! In Puerto Rico, where smallpox was an important disease before the American occupation, only 137 cases appeared in the eleven years, 1913 to 1923. In the unprotected state of Washington, with about the same population, there were, during the same period, 24,183 cases, 176 times as many as in Puerto Rico. If in the states decorated by the antivaccinationists with gold stars, fear does not drive many of the citizens to the protection afforded by vaccination, a serious outbreak of smallpox may be reasonably anticipated such as occurred in Montreal in 1885-86, when the pesti-

lence in its violent form swept through an unwary people and killed 3,164, of whom nearly 87 per cent. were children not yet ten years old.

If men and women were isolated individuals, not living together in communities, they might properly exercise their individualism and refuse to be shielded by vaccination, even though its value as a protective measure has been repeatedly proved. But when they live in communities, such of them as are not vaccinated, and are therefore susceptible to smallpox, afford means for the spread of the disease. As it spreads among adults it has opportunities of attacking unprotected children in whom the mortality is highest during the first years of life. Those who advocate abolishing the vaccination laws are demonstrably threatening the lives of helpless infants and are properly branded as enemies of society.

The last of the enemies of society whom I shall consider are those who oppose the use of lower animals for the purpose of experimental inquiry into the nature of disease and into the best modes of treatment. The "antivivisectionists," so-called, are potentially the greatest menace of all, for if their ideas should prevail, the means of continuing the progress which has thus far been made in freeing mankind from debility and premature death would be sharply stopped. That statement can be made with complete assurance of its being correct, because in every aspect of the conquest of disease, the understanding of infection, the progress of surgery and the establishment of measures for public health, mentioned earlier, the experimental methods required the use of lower animals.

In tracing the history of the antivivisection movement it is interesting to compare the testimony before the English Royal Commissions of 1876 and of 1906-10. In the earlier hearings, held only a few decades after the experi-

mental method began to be used effectively for physiological discovery—before the sciences of bacteriology, immunology, biochemistry, experimental pathology and pharmacology had begun to emerge as special disciplines—the emphasis of the antivivisectionists was on the futility of animal experimentation. The defenders of scientific methods in biology had a difficult task to make clear the importance of keeping open for the uses of medical investigators the well-tried ways of experimental discovery, as proved by the advances in physics and chemistry. How different were the hearings thirty years later! At that time by means of animal experimentation the causes of tuberculosis, bubonic plague, diphtheria, surgical sepsis, child-bed fever and other diseases had been discovered; by use of animals the method of detecting socially dangerous diseases such as typhoid fever and cholera had been learned; and by similar experimental procedures effective natural methods of preventing diseases or curing them (as with diphtheria antitoxin, for example) had been devised. The claim of futility had to be modified. Still more must it be modified to-day, because we can now add to the earlier achievements the control of syphilis, the relief of general paralysis, the swift betterment of scarlet fever patients, the check on diabetes and the rescue of victims of pernicious anemia—we can add these victories over disease and death that have recently been won by medical discoveries made directly or indirectly by use of lower animals.

One might suppose that all this evidence would force the antivivisectionists to admit the utility of animal experimentation. To do so, however, would mean a great weakening of their position, for their main argument from the start has been that the process is futile and cruel, and that such futile cruelty

should be stopped. The evidence, however, has caused them to change their emphasis. They now say that, even if animal experimentation has values, the values are purchased at too great a price. The animals used in experimental laboratories, they declare, are subjected to fiendishly cruel tortures, tortures too awful to be permitted to continue, no matter what benefit may come therefrom to mankind. In their present view, the question is ethical. The animals have rights which we must respect. Not to do so, in so far as laboratory use is concerned, is an affront to the finest feelings in the heart of man and is the cause of callousness and brutality in the experimenter which lead him gradually into worse and more extreme and more degrading acts of violence. Therefore, away with the whole hideous process. Abolish it. Shut up the medical laboratories. Stop studying disease experimentally, stop trying to find remedies by animal tests. That way is closed.

Who are these antivivisectionists, may I ask, that any one should respect their opinion as to what shall and what shall not be done to save human life? Judged from the appearance at legislative hearings and the quoted opinions in their literature, they comprise many women, a few clergymen, some lawyers, writers, actors and business men, who, however sincere and well-intentioned, are grossly misinformed. They cite for support of their attitude the opinions of so-called "doctors," who on investigation are found to have died so long ago that they had no knowledge of the beneficent effects of modern experimentation, or who are devotees of fantastic medical cults, or who made their reputations in literature, art or theology and not in the service of healing. As the second English Royal Commission reported, their "harrowing descriptions and illustrations of operations inflicted on animals, which

are freely circulated by post, advertisement or otherwise, are in many cases calculated to mislead the public." Neither the quick nor the dead among the antivivisectionists testify on the basis of actual experience. They have not entered the laboratories in which they declare that animals are wantonly tortured, they have not seen the operations they criticize, they have not had the background of experience which would allow them to judge properly the reactions of anesthetized animals, they have not had the training which would permit them to interpret intelligently the technical articles which they read, and in place of personal acquaintance with the facts they have let their sentiments and their imaginations have full sway.

For more than forty years in this country members of the medical profession have been fighting to maintain freedom of research. From the first they have claimed that nothing has been adduced to warrant the passage of special, class legislation directed particularly against medical investigators, but that the ordinary anticruelty laws are as applicable in the laboratory as in any other place. All that need be done, if cruelty is suspected, is to make a charge and demand an inspection. Never, to my knowledge, in all these forty years has any antivivisectionist made use of the existing law in this manner.

About twenty-five years ago the American Medical Association established a Committee for the Protection of Medical Research. Immediately it began an inquiry into the conditions under which animal experimentation was being conducted. It found that for years in the older laboratories rules had been formulated and prominently posted, declaring the precautions and expressing the humane spirit which should govern the experimental procedures. These rules the committee summarized and revised

in such ways as to render them generally applicable. By the end of the year 1910 these revised rules had been adopted in practically all laboratories of medical schools in the United States. They have since been adopted in institutes for medical research and in many laboratories of state and city boards of health. Thus, by self-imposed regulations, investigators have publicly defined the safeguards which had been taken and which would continue to be taken to avoid the infliction of pain and thus they have made clear to all who enter the laboratories that work done there shall exhibit that intelligent compassion characteristic of medical service. I would emphasize the point that this mode of self-government of investigators who use lower animals for biological research and for solving problems of disease has been enforced in some of our most prominent medical schools during the past half century.

So certain was the committee that the conduct of animal experimentation in the United States is in the highest sense humane that in 1921 it secured the adoption of the "open door policy." In accord with that policy laboratory officials throughout the United States declared their willingness to admit at all times representatives of humane societies who might wish to know the conditions under which animals are used for research. The only condition laid down was that such visitors must previously have seen an operation on a human being in order to be able to appreciate the humanness of the laboratory methods. This policy was given a large publicity. In 1922 the Blue Cross Society, an organization for the humane care of animals, widely circulated excerpts from the letters of deans and directors of departments, testifying to the enforcement of the rules for the regulation of animal experimentation and to the maintenance of the open door policy.

Such are the conditions under which animal experimentation is now carried on in the United States. The medical investigators testify that they know nothing of the tortures, the horrible cruelties, the secret atrocities which, in the imagination of antivivisectionists, are inflicted on helpless animals in laboratories. The investigators declare, in fact, that the vast majority of operations on animals are practically painless. And in spite of being branded as "fiends," "demons," "human monsters," the investigators are, I believe, persons whose word can be trusted. They are trained scholars; as men of science their service to their fellow men consists in the search for and the establishment of new facts; their eyes and ears are exercised in exact observation; and they are constantly disciplined to draw only justifiable inferences from what they observe. It would seem, therefore, that they are fairly well qualified to report the events going on about them. When they report, they do so fully and precisely, in order that others, who may wish to follow their course and push further into the unknown, shall not be led astray. Desire to find something new and important and verifiable and the wish to report exactly what is found are the ideals which govern the activities of scientific investigators. The pursuit of these ideals is excellent training in telling the truth.

We should recognize that these investigators are the direct successors of the pioneers who, according to Osler, by the experimental study of physiology and pathology "did more in the half-century between 1850 and 1900, to emancipate medicine from the routine and thraldom of authority than all the work of all the physicians from the days of Hippocrates to Jenner" (about 2,200 years!), and he added, "we are yet but on the threshold."

That in brief is the gist of the situa-

tion. In a few decades the application of the experimental method in medical research has wrought marvelous advances in our ability to conserve human life. I need not list again the diseases brought under control or abolished, the release from appalling dread, the opening of the door of hope, that have resulted. But there is much more to be done. We have not yet mastered measles, nor fathomed the mystery of infantile paralysis, nor have we learned the secret of the world-wide plague-like visitations of influenza, we know little of the cause of fatal maladies of the kidneys and the liver, we stand almost helpless before mental diseases, victims of which fill more than half of our hospital beds; and without surgery we are unable to deal with the awful scourge of cancer which kills about 1 man in 7 and 1 woman in 5 if they have passed their fortieth year.

Knowing, as we do, that the method of animal experimentation alone has largely delivered us from the bondage of disease, and certain, as we are, that that method gives us the fairest promise of further deliverance, what shall we do? Shall we cease our efforts, as the antivivisectionists demand? Shall we let men, women and children, whose suffering extends to every one bound to them by love and sympathy, continue their suffering because its cause is a mystery, which we must not solve? In the presence of human woe is it immoral to use lower animals to mitigate that woe? We do not hesitate to interfere with the liberties and life of animals for other human benefits.

We force the harnessed horse to work, and in time of crisis, we drive him with lash and spur. We rob the mother cow of her calf, and then appropriate her milk. We permit the dehorning of cattle and their branding with hot irons. We do not object to the most shocking barn-yard operations, performed (without the sniff of an anesthetic) merely to make more

palatable the flesh we eat. We slaughter ruthlessly, for sport, myriads of birds and beasts. Myriads more we slaughter for their furs and feathers. We kill for food every year in this country more than 50,000,000 beesves, sheep and hogs, and also 250,000,000 chickens, turkeys, ducks and geese. In nineteen of the largest cities in the United States more than 350,000 dogs and cats are destroyed annually, merely to clear the streets. Vermin and wild animals we subject to death in uncertain traps or end their existence with distressing poisons. If all injury and destruction of animal life is immoral, why do the antivivisectionists select as an object for attack the treatment of the relatively few animals employed in the laboratories with the object of reducing pain and suffering in the world?

But as Professor John Dewey has clearly seen, the question at issue is not merely a balancing of physical pain of human beings and of animals against each other. Instead, "it is the question of a certain amount of physical suffering to animals—reduced in extent to a minimum by the precautions of anesthesia, asepsis, and skill—against the bonds and relations which hold people together in society, against the conditions of social vigor and vitality, against the deepest of shocks and interferences to human love and service."

"No one who has faced this issue," Dr. Dewey continues, "can be in doubt as to where the moral right and wrong lie. To prefer the claims of the physical sensations of animals to the prevention of death and the cure of disease—probably the greatest sources of poverty, distress and inefficiency, and certainly the greatest sources of moral suffering—does not rise even to the level of sentimentalism."

"It is accordingly the duty of scientific men," he declares, "to use animal experimentation as an instrument in the promotion of social well-being; and it is the duty of the general public to protect these men from attacks that hamper their work. It is the duty of the general public to sustain them in their en-

deavors. For physicians and scientific men, though having their individual failings and fallibilities like the rest of us, are in this matter acting as ministers and ambassadors of the public good."

There is a statement in the last paragraph, which I have just quoted, that I wish to emphasize—it is the duty of the general public to protect medical investigators from attacks that hamper their work, and to sustain them in their endeavors. That is a welcome note. For decades these investigators, unlike their fellows in physics and chemistry, have had to appear almost annually before legislative committees to argue for the privilege of continuing unhampered their services to human welfare. Although many scientific societies have passed strongly favorable resolutions, only the organized medical profession in the state and the nation has given active support. It is high time for society as a whole to recognize that it has in the antivivisectionists dangerous and resolute enemies and to take steps to thwart their efforts.

In conclusion, may I point out that the medical profession has not only helped to protect society from being endangered by the pernicious activities of the antivivisectionists, but also from being misled and deceived by ignorant "healers." In the main the profession has urged that all who wish to practice the art of healing should submit to the single standard of passing an examination on the structure and functions and the possible disorders of the human body, before being allowed to practice. Because it has supported that fair and uniform requirement, which would prevent quacks and charlatans from exploiting the uninformed and incautious sick, the medical profession has been charged with being a ruthless "trust," seeking solely its own advantage, and eager to exclude all competitors. That charge of corporate selfishness might be

entertained if there were any evidence to sustain it. The historical record, however, is against it. The medical profession has from the beginning supported measures for public health; it has supplied the health officers who protect our cities and coasts; it has agitated for clean water which has abolished the devastating water-borne typhoid epidemics; it has worked for conditions which have greatly lessened the incidence of tuberculosis, yellow fever, malaria and hookworm disease; in its own group it has insisted on high standards of education and professional service—in short, as these illustrations demonstrate, the profession has sought to abolish, not to increase, disease; it has striven earnestly, not for its own advantage in the mean sense of the word, but for the advantage of the social organism of which it is a part. Whenever any other professional groups—lawyers or engineers, for example—can show a record that even remotely approaches that of our own for disinterested public service, we may begin to think that we have not kept up our traditional reputation. For the present we lead. But we usually

lead as an isolated and distinct group in the community—as a medical “bloc.” Since our purposes and those of society are really one, we should cooperate to a greater degree with intelligent and social-minded members of lay organizations. Thus the medical profession would serve, not as a separate organ of the body politic but as one of the cooperating parts, helping, and not carrying the whole responsibility, in the defence against social enemies. By such an alliance the threatened intrusive perils from organized minorities can be effectively met. Concerted action of public-spirited physicians with well-informed members of the community—members of women’s clubs, chambers of commerce, parent-teachers’ associations—could change the defense to aggressive attack. And by aggressive attack we may hope for still further freedom—freedom from the dangers to the common weal from spurious “doctors,” from persons who refuse to accept measures to protect the public health and from fanatical agitators who strive to check the beneficent advancement of medical knowledge.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

WAYS OF THE BEAVER PEOPLE

By VERNON BAILEY

U. S. BIOLOGICAL SURVEY

THE old Indian idea of considering many animals as just other kinds of people, different from our kind but not so very different, is evidently based on close association and real understanding of animal habits and natures. Their Coyote Man, the Bear People and the Beaver People are significant terms. They often name their sons for some animals of special bravery, prowess or intelligence, as no doubt our ancestors did before the psychologists tried to prove a wide and impassable gap between man and other animals that we class as lower down in the scale of life. There are great differences, but mainly mere differences of degree.

There has been much romance written about the beaver, but nothing more interesting than the actual facts. They are not human nor superhuman, as some would have us believe, but they are very intelligent animals in their own way, and from youth to old age they lead interesting and useful lives, if given half a chance.

The baby beavers, Paddy and Johnny, that Mrs. Bailey and I raised from a few days old in early June to big husky young beavers in the fall, were very like children in the family. They had many of the ills and accidents of children, cried exactly like babies when hungry, loved to be rocked to sleep after meals and to be wrapped in their woolen blanket and taken into a warm bed when they were cold. In return they gave us the most friendly confidence and a slight degree of obedience.

Another pair of young that, before I knew them, were kept all summer for exhibition to the public at county fairs took a strong dislike to the human species and never became friendly. When given a comfortable and convenient house in the park, with a warm nest box and a water hole into the pond, they were happy until I came in through the back door. Then they slapped their tails on the wet floor and refused to be comforted until I went away. That night they piled all their sticks against the door to keep me out. When this was not successful, they went around behind the house and piled sticks and mud against the outside of the door almost to the top and plastered up the cracks with mud as high as their skilful hands could reach, with the evident intention of barring me from their home. Later, when I had to catch them and saw off their upper incisors, which had grown too long from lack of wood to cut, they were very angry and tried both to escape and to bite me, although they were not being hurt in the least by the necessary dentistry. Another beaver in the house with them, caught in the wild when full grown, was comparatively gentle and friendly.

The only other beaver I ever handled that was cross with me was an old female that had previously been caught in a steel trap and lost one foot and naturally had gained a very poor opinion of human people. She would actually chase me until I was glad to put her back in the lake where she came from.

To test the intelligence and skill of an Adirondack beaver, I once cut a notch in the top of a well-kept beaver dam that held the water in a clear deep pond surrounding a large beaver house. This was before sundown in the afternoon of a bright autumn day. The beavers had been cutting and storing wood for their winter's supply of food to be eaten under the ice, and they knew as well as I the importance of keeping the pond full of water.

After seating myself comfortably on a high bank above the dam I waited while the water roared out through the break with a sound that easily carried through the still water to the beaver hole in the bottom of the house where the family lived. In about ten minutes a ripple appeared near the house, and then a V-shaped wake came directly toward the broken dam, its apex marked by a blunt nose, two bright eyes and a pair of low round ears. As the wake stopped close to the break the broad back, flat tail and webbed hind feet of a large old beaver floated at the surface for a full minute, while with keen senses alert it studied the surroundings for a possible enemy. It may have been Mrs. or Mr. Beaver. No one could ever tell in the water and few can tell on land, but we will call him "Mister." The coast seemed clear, for I was above and down the wind and knew how to keep still.

Soon the old beaver came up into the break, sat in the rushing water, and eyed the broken banks on both sides. He was evidently puzzled for any logical cause of the trouble, but his thoughts were of a practical nature. Returning to the pond he disappeared just above the dam and soon came up with both arms full of mud and trash from the bottom, pushed it up on the dam and into the broken notch, sat for a minute and watched while the rushing water carried it all away, then started up the pond to a steep bank and cut off a stout bush.

This he brought to the dam and with both hands and his teeth pushed the butt end into the mud at one side of the break. Then he swam out in the pond, dived to the bottom, brought up a stick about two feet long, swam with it in his big teeth back to the dam, and pushed one end down into the other side of the break. Then, without stopping longer than to see that it held firmly, he swam to another spot in the pond and brought up a long limby stick and laid it cross-ways against the two sticks, clear across the rushing stream. It stayed where placed, but only made the angry waters roar the louder. The beaver then brought up another big armful of trash from the bottom and pushed up against this cross stick and as rapidly as possible brought load after load of mud and trash until the water stopped roaring, then stopped running over the dam, and the job was done.

I forgot to look at my watch, but should guess at the time as twenty minutes for the whole repair job. It was thorough, final and satisfactory, and after carefully inspecting it the beaver went back to the house and disappeared underneath by way of the water door into his comfortable nest room inside. This was just an incident in his day's work, but it showed thought, planning, skill and understanding. All it lacked of human intelligence was the bill for five dollars for plumbing repairs that he should have sent to me.

A well-made beaver house beats any barbed-wire entanglement for strength and impenetrability of structure, besides being cold-proof in winter and heat-proof in summer. It may have an unkempt appearance externally, but inside it is a model of comfort and convenience. With a clean bed only a little above the water door in the bottom and a little extra room for sticks that are brought in for food, housekeeping is simplified to its lowest terms. The bathroom is out-

side and there is plenty of room in the lake or pond for social affairs.

There are also bank burrows, which often are safer than houses, because they are entered below the water level, in high lake or stream banks where well hidden from all enemies. The nest chambers are as safe and clean and comfortable as could be desired, and the entrances are deep under water.

Beavers are hearty eaters, and the problem of an ample winter food supply is of vital importance. Enough good green wood must be cut and stored in deep water to last the beaver family or colony through the winter, or from the time the ice seals the ponds late in fall to the time when it breaks up in spring. Only the fresh green bark, twigs and buds are eaten, so it takes a lot of wood, and many trees must be cut down, cut into sections that can be dragged to the water and floated to the storage place. Often long canals must be dug through the low ground so heavy sticks and small logs can be floated most of the way from the woods.

This keeps the whole family working like beavers all through the fall storage time right up to cold weather when the ice comes to stay. Everybody works. The big old male may lead the way, but he is eagerly followed by the mother beaver, who may be just as big, strong and wise, by several husky yearlings, and last of all by four or five young of the year, eager to help. While at first mainly in the way, the young soon prove very useful in carrying branches and small sticks to the food store. There seems to be no supervision, no subdivision of labor, no idle boss, but everybody knows what to do and how to do it and enjoys hard work and long hours.

At my camp on the edge of a beautiful lake in northern Michigan the whole gang would swim by to their cutting ground before dark and come straggling back to their house just before sunrise

in the morning. The big old patriarch would be the first to start and often the last to return. Every morning showed more clean-cut stumps and less aspen trees standing in the sidehill grove where the beavers were cutting their timber, and because the trees were small and some of the beavers large, not a tree was left on the ground or lodged in the branches of other trees, as often happens. They were building a new house and making their stores near it, but still sleeping daytimes in a big old house just beyond my camp, so I had a good chance to watch them as the work progressed.

Before the lake froze over they had a regular haystack of logs and sticks and branches of aspen, birch and alder resting on the bottom of the lake in ten feet of water, with brushy tops sticking out above the surface. There were tons of it, all to be peeled and the bark and twigs eaten before spring. Most of it would be cut in short lengths and carried into the house and eaten at leisure, but the larger pieces would have the bark peeled off and eaten where they were, for beavers' mouths are arranged so they can chew and eat under water as well as out.

I wasn't there the following spring, but last spring's remains of peeled sticks over the bottoms of the lakes and ponds near beaver houses were ample evidence of the winter activities. A few sticks are generally found in a beaver house, but when the bark is eaten they are soon carried out. Even the bare peeled sticks are not wasted, for they are just right for building up the house walls and beaver dams when needed. In summer there is abundance of good beaver food everywhere, in the water and out, all sorts of good green leaves, tender growing stems, nice starchy roots and bark when they want it. Winter has been a restful playtime, spring is full of leisure and tempting odors and wanderlust.

Mrs. Beaver must stay at home, for

she will soon have a new family of four or five or six dear furry little paddle-tailed babies to care for, and the old house must be fixed up safe and warm for them or else a clean fresh burrow and nest room made in a high bank where nobody can ever find them. She will be busy and couldn't think of leaving home, but Mr. Beaver and all the last year's children can go where they please and see as much of the under-water world as they like. They will not be needed until next fall when the food harvest begins again.

If it wasn't for their beautiful fur coats and the heartless fur trappers, they would live happy and contented

lives and have less to worry about than some of our people have. If the trappers would display more intelligence and use only live traps that would catch the beavers without any injury or discomfort and then release all but the older animals that had outlived their usefulness and had prime pelts, there could be plenty of beavers anywhere in suitable places. They would then be a valuable asset to the country and one of the most interesting forms of wild life for our study and for the enjoyment of all who are interested in a better knowledge of our animal friends.

The beavers' good-by is a slap on the water with his tail, so — — —

FIGHTING INSECTS WITH POWDER AND LEAD

By Dr. A. L. MELANDER

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FIRST of all, this title suggests the old story of the woman asking the drug clerk for a package of powder. "What kind of powder to you wish—gun, face or insect?" When man wages war on man powder and lead are used, and in the warfare against insects insecticidal powder and lead as poison and lethal gas are employed. The powder is a poisonous dust, the lead is combined with arsenic as arsenate of lead, and the gas may consist of nicotine fumes or deadly cyanogen. Chemical warfare on insects has become an accepted part of our yearly life. It will never be outlawed because of humane feelings for our enemies, and in time to come will decide whether man or insects will dominate this world.

From earliest times insects have afflicted man, destroyed his crops, spread disease and attacked his domesticated animals. As more and more land is farmed, insect pests have increased in

numbers and in their depredations, until now in the United States alone insects destroy each year the products of the labor of a million men, a money loss of at least one and one half billion dollars.

There are many million-dollar insects, several species costing us even a hundred million dollars annually by their destruction of our food and by the expense of our attempts to check their depredations. Chinch bugs swarm in the fields of corn and wheat of the Middle States; the wheat aphid and the Hessian fly of the Mississippi Valley ravage the wheat crop; potato beetles have invaded practically every potato field throughout the continent; the San José scale has spread so rapidly through orchards from coast to coast as to make necessary state laws for the compulsory spraying of fruit trees, the sorting and grading of picked fruit and the condemnation of all fruit found infested; the codling-moth makes

apples wormy, for the control of which an army of men must spray trainloads of poison over millions of apple trees.

The combined destructiveness of the insects just mentioned amounts to hundreds of millions of dollars each year. These insects are racketeers, who exort this toll from the producing farmers, and then the farmers, of course, must pass the cost on to the consuming public. We may think that five cents is cheap for a loaf of bread, but if there were no insect pests of wheat the cost could be four cents. When we pay five cents for an apple we should remember that one cent of this goes for the spraying which alone made it possible for that apple to appear on the market. If the spraying had not been done, that apple would have been wormy or sealy or scabby or deformed by *aphis*, and unsalable.

People who live in cities have little idea of the actuality and the extent of the warfare waged upon insects. The household atomizer is replaced by motor-driven and operated spraying machines. Trainloads of spray-poisons are used. Whole communities of men participate in the battle. Of the twenty-seven million people who live on farms in the United States, nearly all at some time or other must aid in fighting insect pests.

In the Middle West, county campaigns are organized to distribute poisoned bran for grasshoppers. In California, orange groves are subjected to poison gas, the trees being covered with canvas tents and deadly cyanogen gas administered within. In the South, airplanes shower poison dust over cotton fields to destroy the boll weevil and the boll worms. In every commercial orchard from Washington State to New York State, the chugging of engine-driven spraying machinery can be heard.

While the number of insect enemies may appear large on account of the aggregate of their depredations, the actual number of insects pests is fortu-

nately small. Of the insects found in any locality, the vast majority are of little consequence to man, neutral to our economy, feeding on wild plants or upon each other. Only relatively few species are pests in that they eat the plants we grow for our own food, or harm our animals, or even directly attack ourselves. However, since insects far outnumber all other animal species taken together, there is scarcely any limitation in possibilities that insects may become pests when transported to new localities. We do not know what is in store for us, as the future will introduce new insects to this country from foreign shores.

Far-reaching consequences often originate in trivial happenings. When in 1866 an amateur entomologist in Boston imported some specimens of the gipsy-moth from England in an effort, so the story goes, to cross this insect with American moths, hoping thus to develop a silk-producing strain, his experiments might be regarded as praiseworthy, or at least of nobody's concern. Certainly no one at that time could foresee the portentous consequences when a specimen escaped from the cage into the woods near by.

The progeny of that alien moth have caused millions upon millions of dollars to be expended in New England alone, in the unsuccessful attempt to exterminate their race. Huge federal and state appropriations have repeatedly become necessary to subjugate this pest. The Gipsy-Moth Commission was created to investigate ways and means to keep the moth from spreading. Forces of inspectors have had to be maintained. Expert entomologists have scoured Europe and Asia in order to discover the natural parasitic and predatory insect enemies of the moth and to liberate them in the stricken regions here. The extensive warfare upon this invader has exterminated many innocent native insects, whose right to a place in this world

would not have been questioned. Quarantine laws have worked economic hardship on the sellers of produce from the infested localities, Christmas trees, lumber and even quarried granite having been banned as possible carriers of the eggs of this moth. In order to guard against the introduction of other insect pests, federal quarantine laws have been enacted, which at times have threatened diplomatic relations with countries whose produce has been refused admission to the United States.

The gipsy-moth in its caterpillar stage is practically omnivorous. It feeds on the plants of the farm, in woodlands and forests and on ornamentals. It is prolific and exceptionally hardy. Its eggs are often concealed. Many of its caterpillars feed in the tops of trees out of reach. With no knowledge of practical insect control available fifty years ago, no wonder that the destructive spread of this insect through New England was regarded with alarm, lest it sweep across the entire country and its billion dollar toll be multiplied manyfold.

The gipsy-moth is widely distributed through Europe and Asia, but it is not particularly destructive there. In the long ages it has reached a state of equilibrium, held in check by its native enemies. Certainly no country in Europe or Asia would appropriate millions of dollars for its study and suppression. But coming to America, unhampered by its parasites and predators, it was free to propagate and it spread with startling rapidity.

Similar unrestrained multiplication has commonly followed the introduction of other pests to this country. Most of our serious destructive insects are not native, but have come to the United States from near or from far. The San José scale was accidentally brought from China, the bean beetle and the boll weevil from Mexico, the fluted scale from Australia, the codling moth,

oystershell barklouse, red spider, earwig and many kinds of aphids from Europe. Such names as Japanese beetle, European corn-borer, gipsy-moth, Mediterranean fruit-fly and Asiatic beetle impinge that these insects are not native Americans.

The United States has been the land of the free to many foreign insects, but now such anti-social immigrants have greater difficulty of introduction because of the inspection maintained by various border-line states and by the Federal Plant Quarantine and Control Administration, through whose vigilance it is hoped that the costly mistakes of the past will not be repeated. It is impossible to tell beforehand whether an insect species of little consequence in another country when brought to America may multiply prolifically and do immeasurable harm.

Before the gipsy-moth invaded Massachusetts, insect poisons and spraying methods were almost unknown. The Gipsy-Moth Commission established by Congress entered a pioneer field. Its investigators had to invent and develop pumps and nozzles for spraying and experiment with possible poisons. Their problem was to find a substance poisonous to the insect, yet harmless to the foliage on which it was applied, something economical, durable, easily mixed and applied, compatible with other materials, adhesive, not distasteful to the insect, and quick acting. It was probable that no such substance existed. Many known poisons when tried proved to be injurious to the plants when fatal to the caterpillars. Many washed away during rains. Some were repellent in taste. Others were too expensive for general use. Arsenate of lead alone possessed the attributes of an ideal insecticide, but hitherto it had found no use and was merely a chemical curiosity, only a few ounces of it being in existence in chemical museums. Now it is a staple com-

modity made by thousands of tons at a cost of but few cents per pound, and is used not only on the gipsy-moth but as the main protection against all fruit- and leaf-eating insects of orchards, garden, field and forest the world over. The act of Congress in establishing the Gipsy-Moth Commission laid a foundation for a new science of applied entomology.

If the gipsy-moth had not been a spectacular insect, and if it had not first invaded the property of influential Bostonians, and if Congress then as now had been motivated by nearsighted policies for economy, perhaps this scientific commission to discover means of repression of this local immigrant might have been regarded as an unwarranted extravagance. Time has shown that the far-reaching benefits from this study, however, have repaid the costs a thousandfold, and this should be remembered when retrenchment arguments are made against preparedness for the next insect war.

Some people excuse war because it brings out inventions and teaches efficiency, that while war brings immediate hardships its far-reaching results are beneficial. Such people find in the war-cloud against insects a silver lining in the discovery of improved methods of pest control, better farming practise, an improvement in the quality of fruits and crops and better prices to the producer. It is true that the scientific investigations necessitated by the gipsy-moth, the cotton boll weevil, the San José scale, the codling moth and other major insect pests have enabled farmers to produce crops despite their enemies.

If we knew no more about insect control than our grandfathers did, the greatly increased number of insects now occurring in the United States would bankrupt us as a farming nation. In a sense scientific methods have led to an overproduction of some products just now. Last year produced more cotton,

corn, wheat, oranges and apples than found a profitable price on the market, but this condition was due to marketing inefficiency and the economic depression rather than to the growing of too much produce.

The world is still increasing in population. Statisticians assure us that at the present rate of increase of births over deaths forty million more acres of land must each year be brought into cultivation than the year before to keep us in food, that each year the world must produce twenty-three trillion pounds of food more than the year before. Since the amount of unoccupied land suitable for farming is decidedly limited, the time is not far distant when an outbreak of some insect pest will bring wholesale starvation. Perhaps our grandchildren, certainly our great-grandchildren, will know what it means to go hungry because the grasshoppers have eaten the wheat and corn.

People in China and India already perish by the million because of insect-spread diseases and because of crop failure. Horses and cattle on the Western range drop of starvation, due to drought and locust attack. Before them herds of bison were exterminated when hordes of insects wiped out their feeding grounds. It is a truism that the most deadly enemies are the small ones. Cutworms and grasshoppers are destined to be more terrible destroyers of mankind than wolves and lions.

Applied entomology is a youthful science, and with the boast of youth it realizes its achievements and importance. But it also knows that pest control requires continued investigation. Powder and lead have made possible the growing of some crops, but it would be folly to limit our dependence to their aid. The strength of the spray, the proper formula, the use of spreaders, adhesives, lures, baits or repellents, the possibility or impossibility of combining various

treatments and the time of application can not be predetermined, but require detailed experimentation. Some insects can not be reached by spraying; sometimes it is impractical to spray. Fruit-growers dread the accumulation of arsenicals dripping into the soil. Boards of health condemn oversprayed fruit. Some insects seem to be developing a resistance to standard treatments. Should pests in general become immune to treatment, the import is most ominous.

As a matter of present economic relief to the farmer and to the ultimate con-

sumer, as well as preparedness against inevitable future invasions of insects, it behooves us as a nation to find means to stop the billion dollar waste caused by these Lilliputian enemies. Curtailment of appropriations for scientific investigations is certain to prolong a period of depression and not to terminate it. In biblical times, when the locusts swarmed over Egypt, the afflicted peoples turned to Moses for relief, and he said "Let us pray." Nowadays the materialistic farmer appeals to the entomologist, and he says "Let us spray."

PLANT SOCIOLOGY

By Dr. HENRY S. CONARD
PROFESSOR OF BOTANY, GRINNELL COLLEGE

THE youngest and newest of the great family of plant sciences is plant sociology. It has a definite history of about fifteen years. But in truth it is a development of good old common sense about plants as they actually grow in nature. It attempts to put in order what all field botanists, farmers, foresters and flower lovers know, and to enrich and deepen and organize this knowledge.

The word sociology can be applied to plant life only in a somewhat figurative way. In human society we have the conscious cooperation of individuals or the conscious lack of cooperation, directed to the accomplishment of some aim or plan for future achievement. Obviously this does not occur in plant societies. Trees may get their heads together, but they do not lay plans.

But there are also many social relations in human and animal societies which come about without any planning. The mere existence of two persons within the ken of one another brings about a social relation. It is in this latter way that plant sociology re-

sembles the sociology of August Comte. Plants do live together in social units, each plant having an influence upon all the plants in its vicinity. This sociology, both of humans and of plants, has to do with the life of organisms in social units, as distinguished from the life of the individual by and for itself.

The mutual relations of plants may be classed as either dependent or commensal. The parasitic plants which cause disease upon other plants, and even that popular parasite, the mistletoe, are obviously dependent upon the host plant for food and shelter. But our most beloved spring flowers which grow in the rich leaf mold of our forests are just as truly dependent plants. For we all know how quickly the wildwood flowers die out when the forest is cut away. And many of us know that if we would have wild flowers in our gardens, we must provide them with shade and leaf mold.

Nor is leaf mold all one thing. The decay of pine needles produces a strongly acid mold. Oak leaves give a mildly acid humus. But the leaves of

willow, cottonwood and elm produce a neutral, or may even permit a feebly alkaline mold. And so the small plants of the coniferous forest are different from those of the oak woods, and these again differ from those of the river bottom woods of elm, willow and cottonwood.

In another aspect, the trees and flowers are commensals. They feed from the same table, without interfering with one another. The trees need lots of sunshine and they get it. They need constant supplies of water, and their roots go deep to get it. The shade plants want the subdued light which the trees afford; and they are content to draw their food and water from the surface soil which is useless to the trees. Here, then, is a friendly mutualism—a society without competition, but very distinctly a social union.

The minute sociological study of plant societies has yielded highly important results in the hands of European botanists. It is as yet undeveloped in America. Dr. York, when forester for New York State, remarked that when he took European foresters out to see our woods, they scarcely looked at the trees but examined critically the flowers and shrubs and mosses that grew under them. One can read volumes of reports about the trees. But the other members of the society have not been described. And it is exactly these other members, which elucidate the inner nature and the essential details of the social union, the forest. Some of us go abroad, put up at a dozen or two of the best hotels of Europe, and come home full of ideas about social conditions there. We are like foresters who look only at the trees. A sociologist knows that a hotel lobby—especially that of a hotel for tourists—is the last place in which to learn anything of value about a strange country. To learn of social conditions is a long, arduous and technical procedure.

So in plant sociology, an adequate knowledge of plant societies is the product of years of minute and painstaking research. Much can be learned from Rübel's delightful book on "Geobotanical Research" and his more recent one on "Plant Associations," and from the recently translated work of Lundegardh, and from the just announced translation of Braun-Blanquet. In these books many familiar facts find precise expression and a place in the cycle of science.

The old herb gatherer, now nearly extinguished by his own improvident methods, and by the synthetic chemist, was a practical plant sociologist. He knew where to look for gold thread or ginseng. But he didn't know why. Consequently, when natural ginseng became scarce, and it was necessary to cultivate it in order to supply the demand, it was a matter of long experimentation to find out how to meet its exacting requirements. The woodsman knows where to look for valuable maple or hickory or fir. But when it comes to reforestation, the attempts of the woodsman, and even of the forester, often fail. The social relation has not been taken into account. We are still going at it rather blindly, owing to the inadequacy of our knowledge of the social relations of plants.

The farmer can tell a good deal about his soil and its needs by the behavior of crops and weeds in each field. And a good deal has been done in our western plains by Clements and Weaver and their school on the so-called "indicator" value of certain plants or groups of plants. Sage brush will indicate the possibilities of the soil and climate over large areas of our semiarid west. Sage brush land will produce crops if water can be given in sufficient quantity. Greasewood land is alkaline and is either hopeless or will yield crops only after prolonged washing. The purslane weed survives only in cultivated or very re-

cently cultivated land. Jimson weed is often the only survivor in land that has been greatly overmanured; hence its dominance in deserted barnyards and feedlots.

A number of striking and interesting ideas have been crystallized by plant sociologists out of the mother liquor of our common knowledge of plants. For example, everybody who has ever spoken about plants publicly or privately has tried to tell how much of each kind or of some one kind of plant there is on a given area. It is common or rare or abundant or scarce. It helps but little to count the plants and, besides, counting may be extremely laborious. A plot may have three oak trees and a thousand shoots of grass, but the three oaks far outdo the thousand grasses in controlling the situation. The forester will calculate the number of board feet of lumber of each kind on his plot. But that is significant only to the lumberman. For a mature pine will require only 15 square meters of space, while an oak will require much more. The plant sociologist considers first the amount of ground covered by each kind of plant. He imagines the entire plant projected on the ground, as if photographed from an airplane. A wooded hillside may have a 90 per cent. cover of chestnut-oak 60 feet tall, an 80 per cent. cover of laurel or rhododendron six feet tall, and a 90 per cent. cover of mosses on the ground. This statement tells much about the kind of woodland, and the effective quantity of each kind of plant. Thus the quantity of plants is best expressed by their coverage.

A further clearing of our thought is given by the ideas of constancy and fidelity, the extent to which a kind of plant is constantly found in certain kinds of vegetation, and the extent to which it is confined to a certain kind of plant society and is therefore characteristic of it. A plant of high con-

stancy and fidelity becomes an indicator of the local conditions of soil and climate. It is in itself a summary report of the Weather Bureau and the Soil Survey. In southeastern Pennsylvania, the creeping phlox and the big white Cerastium are strictly confined to the societies of Serpentine rock. If you tell me you have wandered under the great coast redwoods of California, I can tell you not only what part of California you were in, but what shrubs and flowers and mosses you should have noticed also. The coast redwood is a "constant" of a certain social alliance. But other plants are almost wholly lacking in constancy. If you found a dandelion, I don't know anything about where you were. Dandelion is ubiquitous. We call it an ubiquist.

The concept of vitality is rarely appreciated without careful consideration. Where is a plant really at home? Where it flourishes and raises progeny, of course. By the test of reproduction, we find great numbers of plants that are away from home—strangers. The evergreens in your yard—do they yield any seedlings? The rhododendrons—do they even set seed? The dogwoods, redbuds, arbutus, harebells, *Mimulus*, wild poppy—are they just holding their own, or dwindling slowly? Are new plants or patches appearing in favorable seasons? Is it well with their vitality? If not, what of the future?

Aggressiveness is another concept of extreme interest. Wherever changes of vegetation are in progress, as on abandoned land or regenerating forest or in a garden or on a farm, what is the aggressiveness of the different plants and societies? Which groups force their way against all comers, and under what conditions? What is going on at the margin of a wood? Which plants are spreading and which retreating, and how and why?

Constructiveness and destructiveness

are equally important ideas. Recently published work of Dr. Blizzard at Cold Spring Harbor, New York, has shown that the shrubby bayberry is highly constructive in that it can grow on bare gravel and there build up a humus soil in which maples and oaks can and do start and grow into valuable trees. The same study shows that grapevines and Virginia creeper and Japanese honeysuckle are highly destructive. They clamber over the tall trees, and cut off the light from the tree leaves, and weight down the tops with an unbear-

able load of vegetation. The forest crumbles beneath the vines.

There is much that is not new in plant sociology; all outdoor folk know the general facts. Like many another science—medicine, mechanics, management—plant sociology gives dignity and precision to the knowledge gained by generations of observant practical men and women. It points the way to the finding of answers to the questions these men and women are asking. In this lies the guarantee of its progress and permanent value.

BAMBOO, THE UNIVERSAL PROVIDER

By Dr. WILLARD M. PORTERFIELD, Jr.

PROFESSOR OF BIOLOGY, ST. JOHN'S UNIVERSITY, SHANGHAI, CHINA

WHEN the claim is made to the world at large that a certain tree is the most useful in the world, it is generally assumed that the person advancing such a claim has been careful first to study the merits of other useful plants. It is also true that a plant universally used in one small part of the globe may not be so used in other and larger regions. I am referring specifically to the claims put forward in an article published in the SCIENTIFIC MONTHLY for September, 1928, entitled "The Most Valuable Tree in the World." The coconut is the tree referred to. The article is pro-coconut exclusively, not one line of acknowledgment being allowed any other plant. In view of the broadcast appeal at the end of this article calling on all and sundry to furnish, if they can, evidence that any other tree "can offer the varied uses of the coconut," I am inclined to doubt whether the author ever considered bamboo.

There is a war in Shanghai and one does not know from day to day what is going to happen, but as college exercises have been suspended I have a little time in which to tell the world that besides the Far Eastern problem there is also bamboo. I can at best in the time and space available only skim the subject of bamboo, but I can at least indicate with a few concrete illustrations the far-reaching usefulness of this plant. Botanical descriptions can be had from technical works, so that I shall not spend time on that aspect. I shall deal only with the uses of bamboo in an endeavor to substantiate my claim that the humble bamboo may dare to rival the coconut as the "most valuable tree on the face of the earth."

To begin with, bamboo is a tree-grass. The culms, aside from their subterranean connections with the plant as a whole, are woody, branched and tall, some species reaching more than a hundred feet into the air. Every year they extend their total leaf surface, in spite of the fact that the culms individually show no increase in girth. Extension of leaf area is balanced by elongation of the rhizome and by the production of more culms. The point is, the aerial part of the bamboo is undoubtedly tree-like and as such can be admitted to the category of trees comparable with the coconut. It now remains only to show that the bamboo is as useful.

In China the use of bamboo extends back into history so far that, when the present ideographs used in Chinese writing were developed, one of the elementary radicals which share in the formation of some of these characters was the one for bamboo, 竹 which is in reality a picture of two culms standing side by side, bearing a branch and a leaf each. It is so linked with the life and customs of the Chinese people that without it the farmer in particular could not get along. In fact, it is said by the Chinese that without one useful plant like bamboo no country can thrive. Not only China, but also Japan, Formosa, the Philippine Islands, Siam, Indo-China, India, Ceylon, Sumatra, Java and the Malay Archipelago are all productive of bamboos, whose uses have been exploited since time immemorial. In other parts of the world the West Indies, Central and South America, Brazil in particular, to which may be added finally parts of Africa and Madagascar, have long



PHYLLOSTACHYS BAMBUSOIDES
SHOOTS COMING UP IN MAY, NEAR HANGCHOW,
CHINA.

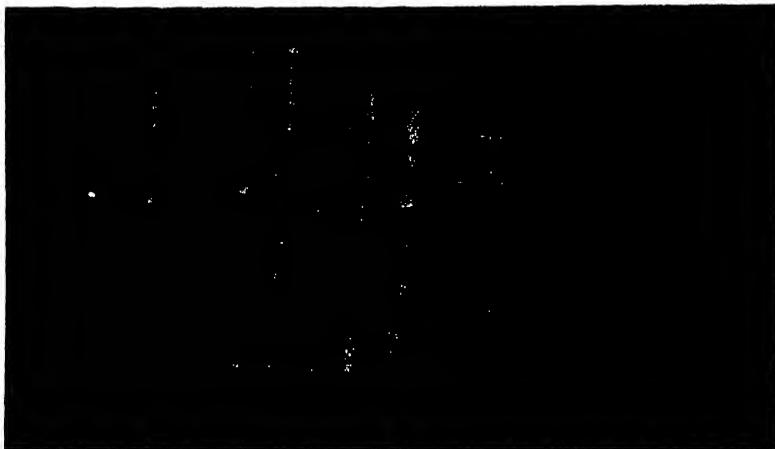
ago availed themselves of their native bamboos.

There are two ways of learning about an object. One is to observe it one's self, the other is to read about it. In my own experience while living in Shanghai I have seen bamboo used for almost every purpose. In my tours of inspection around the campus with the head gardener I have had many occasions to put my O. K. on requests for new bushel baskets, tool handles, carrying poles, basket trays for carrying pots of plants, new fences and fence-posts, ladders, poles to be split into stakes and made into frames for the support of flowers, and poles on which to hang back-nets for the tennis courts, all made of bamboo. Possibly at the time one of the coolies while mowing the lawn was wearing a sun hat made of fine strips of bamboo woven together, while his helper may have been wielding a bamboo stick to urge the donkey to haul the mower "more fast." As we pass an amah comes scuffling along with a big bamboo basket loaded with vegetables which she has just bought in the near-by village. Farther on some coolies who have been unloading coal sit down for a rest. One brings out his tobacco pipe for a brief whiff. It has a diminutive bowl and long bamboo stem. From a bamboo box

made by sawing off one of the short sections from the lower end of a bamboo pole he extracts a pinch of tobacco and fills his pipe. The garage which houses the family Chevrolet, some details of which may be observed on the next page, is made of split bamboo, lined inside with plaster and thatched with rice straw. A tall apartment house just completed, which I pass on my way to town, is emerging for the first time to the light of day through the removal of its screen of split bamboo mats and bamboo scaffolding poles bound together with bamboo thongs. Along the road I pass a native restaurant and observe that the noon-day rice is being kept hot in small buckets made of bamboo slats held together by hoops of stripped bamboo. When I return to luncheon, among the vegetables on the menu are delicious creamed bamboo shoots sliced. From somewhere in the back quarters are wafted in to me the plaintive notes of the bamboo flute interspersed with occasional scrapings and squeaks of the Chinese violin, some of which are also made of bamboo.



GROVES OF CULTIVATED BAMBOOS
NEAR SHANGHAI, CHINA.



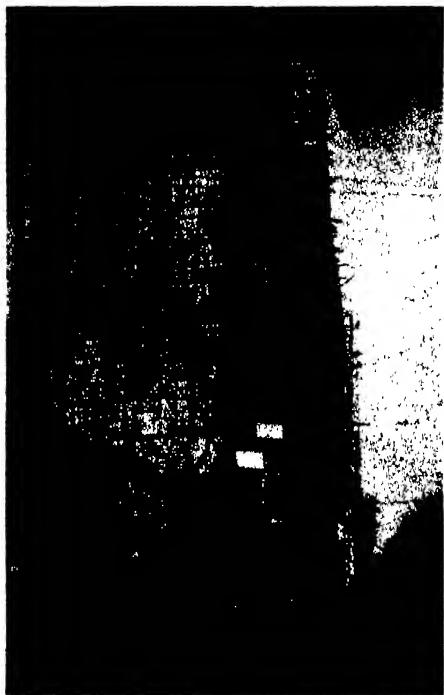
THE FAMILY GARAGE

DETAIL OF WALL CONSTRUCTION WITH WINDOW FRAME AND SHUTTER OF SPLIT BAMBOO.

In pleasant weather on almost any late afternoon in peaceful times may be seen the familiar figures of Chinese gentlemen listlessly plying a bamboo fan with one hand, while carrying a finely made bamboo cage in the other as they stroll about with their pet birds, the women folk in the more conservative families remaining behind doubtless to pass the time playing mahjong with prettily decorated ivory-faced bamboo tiles. High up in the air fantastic centipede kites constructed of bamboo splints zigzag back and forth or float lazily poised, while little sister watches near-by as she tends small baby brother who is ensconced in a sort of basket go-cart made principally out of woven strips of bamboo. Down by the canal a junk is unloading and the stevedores, as they come off with each bale, hand a bamboo tally to a clerk. At the same time an accountant at a table poised pen of bamboo over his ledger ready to enter the item required. As the work progresses I observe that some hands begin taking turns at pumping bilge water out of the junk and perceive that the pump is made of bamboo. Recently on a visit to the country I watched a well being dug in the alluvial silt which

constitutes our land. A bamboo pole sharpened at one end with the partitions knocked out was used as a drill. This affixed to another pole was suspended from a horizontally placed bow made of several bamboo poles lashed together, the whole being 20 to 30 feet in length, which acted like a spring to draw up the drill between blows. In conclusion, I should like merely to mention the fact that in addition to those already indicated there are innumerable ornamental and what might be termed symbolical uses of both living and pictorial bamboo, of which at present there is no time to tell. This brief exposition based on actual experience, it seems to me, is sufficient to justify the name "universal provider" for bamboo. It suggests furthermore that a full study of the uses of bamboo in any region does in itself give one a very good idea of the character and customs of the people living there, so closely is it connected with their daily life.

Let us pass on now to comments about bamboo taken from the writings and experience of others. Supplementary evidence from the observations and experience of the explorers especially will contribute still more support to my

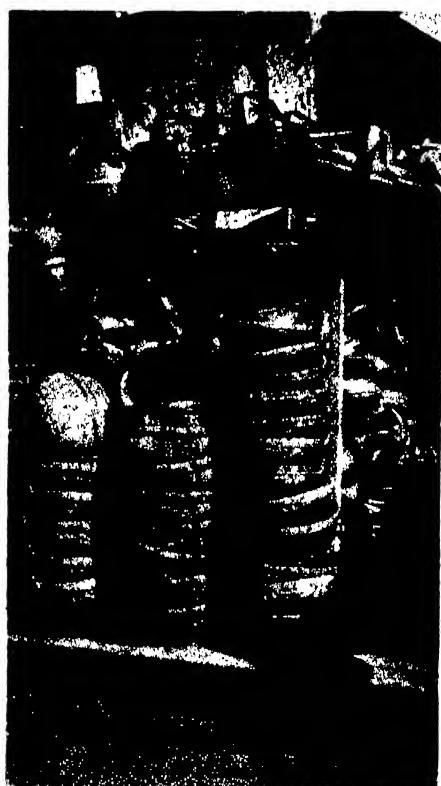


AN APARTMENT HOUSE
WITH ITS CLOAK OF MATS AND SCAFFOLD POLES
AT SHANGHAI.

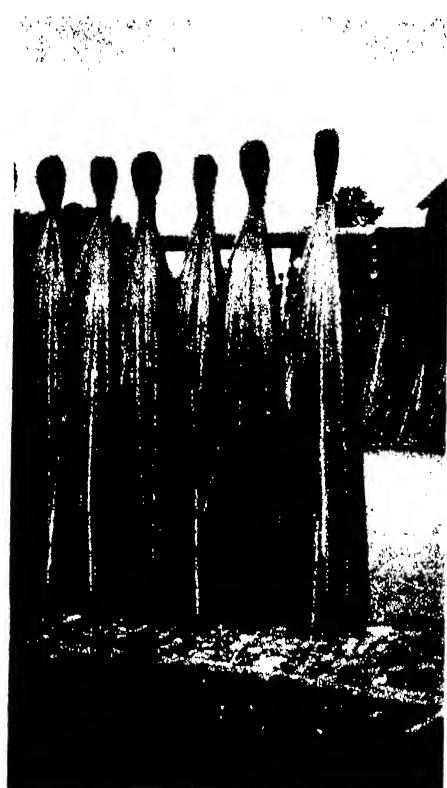
assertions with regard to the usefulness of bamboo. The historic travels of Marco Polo were among the first to reveal to the western world the domestic value of bamboo. He tells how the Chinese manufactured cables for towing ships by first splitting canes their whole length into thin pieces and then by twisting these together into ropes three hundred paces long. It is interesting to note in passing that engineers experimenting for the Whangpoo Conservancy Board found twisted and plaited ropes made with material taken from the outer eighth of an inch of bamboos about four inches in diameter being used to tow junks up against the current of the rapids in the gorges of the Yangtse River and estimated that the working stress was about 10,000 pounds per square inch of the material, this tension every now and then being doubled. Marco Polo

also describes a novel method of protection used by travelers passing overland where there was danger of molestation by wild beasts. Several bamboo poles in a green state tied together, he says, were placed as evening approached at a certain distance from their quarters with a fire lighted around them. The action of the heat on the green wood was to generate considerable steam pressure in the hollow internodes, causing them to explode at intervals with a loud report which frightened away prowling beasts.

During his famous trips to the tea countries of China and India Robert Fortune had the opportunity of observing bamboo in its many aspects. He describes in detail the native method of



SPLIT BAMBOO BASKETS
IN A SHOP AT THE ANNUAL BAMBOO BAZAAR AT
BUBBLING WELL, SHANGHAI



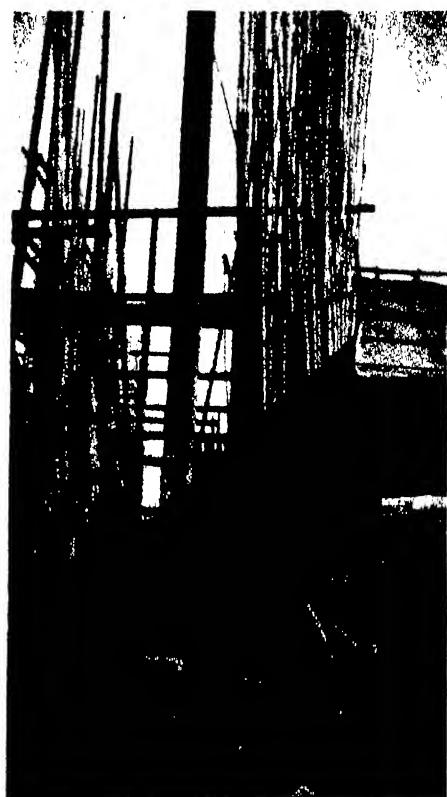
BUNDLES OF BAMBOO STRIPS
FOR BASKET WEAVING HANGING UP TO DRY NEAR
HANGCHOW.

making paper in China. Bamboo was the source used, and the process while laborious was faithfully carried out. Apparently bamboo poles are soaked in water, then split and saturated with lime and water until they become soft. They are then beaten into a pulp by hand or by crude mechanical stampers, after which the mass is taken to a furnace and well boiled until it has been reduced to its finest elements. It is then formed into sheets of paper. Again he relates in interesting fashion the business of carrying poles down the mountains to the nearest waterway, where in the form of rafts they are floated down to the many markets that await them. In the spring the young shoots are also sought out and shipped. In conclusion, Fortune makes the following statement:

"Thus this valuable tree which is cultivated at scarcely any expense gives employment and food to the natives of these mountains (Ningpo to Kwaung-tung) for nearly one half of the year."

There are some very unique uses to which bamboo has been put that might be of interest. E. H. Wilson, in "A Naturalist in Western China,"¹ describes the great bamboo cable bridge which spans the Min River on the road to Monkong Ting. It is 250 yards long and 9 feet wide, and is built with the exception of the floor planking entirely of bamboo cables. There are seven supports placed equidistant, the middle one being made of stone. The cables are twenty in number, ten supporting the floor and five on each side forming the "rails." The cables are made of split

¹ Vol. 1, p. 171.



BAMBOO SHOP IN THE VILLAGE NEAR
SHANGHAI.

and twisted bamboo culms, are 21 inches in circumference and are held taut by large capstans embedded in masonry. The bridge planking is held down with bamboo ropes and the cables are kept in place with lateral strands. Not a single nail or piece of iron is used. This is not the only bamboo bridge in China, and China furthermore is not the only country where bamboo bridges occur. Bamboo suspension bridges are also met with in Java. These, however, are not made with cables but with poles lashed together.

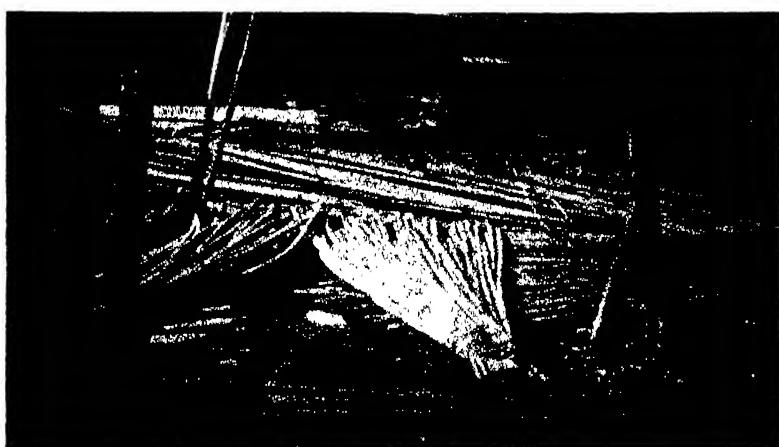
In the Philippine Islands there is an organ built entirely of bamboos, the only one of its kind in the world. It is in the Las Piñas church. The construction of this organ was begun in 1818 by Father Diego Cera and it is said 950 bamboo tubes of different sizes were used. The Shanghai Police Museum of Crime boasts of one exhibit certainly which demonstrates the skill of the Chinese in applying bamboo to use. It is a weighing machine made especially for crickets. Fighting crickets, like prize fighters, are accurately weighed and the machine by which it is done is made of bamboo and a delicate spring. Tabashir is always mentioned in connection with

the uses of bamboo. It is an opalescent accumulation which is found inside the internodes of *Melocanna bambusoides*. The substance is chiefly silica and potash, and according to A. B. Freeman-Mitford, C. B., in his "Bamboo Garden" (1896), it is a famous medicine used for any and all ailments. E. W. Brandes on his expedition by seaplane into Papua² tells of a kind of xylophone made of tubes of bamboo. Photographs also appear with this article of natives wearing nose plugs of bamboo. David Fairchild arouses our respect for the Javanese carpenter in his account³ of the expeditious way in which he can with a few deft strokes of a cleaver flatten out a bamboo culm into so many strips of flooring for the new house that is being built.

One of the most thorough investigations of the uses of bamboo is that carried out by Hans Spörry and published jointly in 1903 with Dr. C. Schröter, who wrote the botanical introduction. The study was undertaken in Japan and concerns the uses of bamboo in Japan only. Spörry lists 1,048 practical uses, which represents really an enumeration

² *National Geographic Magazine*, lvi, 3, 1927.

³ "Exploring for Plants," p. 403, 1930.



RAFTS OF BAMBOO POLES

TIED UP AT THE LANDING AFTER A LONG JOURNEY FROM THE HILLS.



A BAMBOO CABLE BRIDGE

ACROSS THE MIN RIVER NEAR WENCHUAN NORTH FROM CHENGTU. Through the kindness of
Dr. R. G. Agnew.

of Japanese articles of bamboo contained in his own collection. The remainder up to the total 1,546 includes also the ornamental uses. These uses with variations would stand almost as they are for China, too. The best accounts of the uses of bamboo in China can be had from the fifth edition revised of J. Dyer Ball's "Things Chinese."⁴ The names of 83 uses are listed and these are in the form of general headings only, taking no account whatever of the many variations under each heading. The term "ornaments" alone, which is one of these, includes a great many articles. Again, Dr. S. W. Williams in the first volume of his "Middle Kingdom"⁵ enumerates 82 uses of bamboo. Every part of the plant is used in some way. The shoots, roots, canes and leaves are all represented. The uses of the canes can roughly be classified under the form of the cane employed, *viz.*, canes, strips, splints, shavings. The leaves too serve as thatching material, lining for tea boxes, raincoats, large umbrellas, the

larger leaves of forms like *Sasa tessellata* being used for wrapping sweets of certain kinds. In addition to those mentioned by Dr. Williams I would like to add that I have seen farmers around Hangchow wearing sandals made of the tough leathery sheathing leaf which covers the shoots of *Phyllostachys pubescens*. E. Hackel, in *Natürlichen Pflanzenfamilien*,⁶ discusses the uses of bamboo generally. Among the 58 uses mentioned every kind of an article is included from Chinese junk masts to Burmese snuff boxes. We are surprised to learn that the production of great masses of seed, following one of those rare flowerings of the bamboo, while it may supply the countryside with a fair substitute for rice in case of a shortage at the time, is not an unalloyed blessing. On the contrary, it supports a tremendous increase in the rats and mice which, when the surplus of bamboo seed has been devoured, overflow into the neighboring fields and destroy the crops growing there. Such is the experience of the German colonies in the Brazilian prov-

⁴ 1925, pp. 59-63.

⁵ 1883, pp. 358-360.

⁶ Engler and Prantl, II Teil, 2 Abteilung, pp. 89-97, 1887.

inces of Santa Catharina and Rio Grande do Sul about every thirteen years.

One can not live long in a country where bamboos grow and are used by the people without feeling that bamboo has contributed a great deal to the progress of that people and that the mastery of its uses marks a cultural stage in the development of their civilization. One becomes still more convinced of this fact after reading such accounts as that of David Fairchild of the bamboo civilization of Java.⁷ Archeologists would indeed be justified in incorporating in their historical outlines for tropical and sub-tropical Asia a definite Bamboo Age comparable with that of Stone or Bronze. With a material which lends itself so readily to manipulation it is no wonder that native craftsmen soon found it a field for exploiting their genius. Because of its great tensile strength, its capacity for splitting

⁷ "Exploring for Plants," Chapters xxx and xxxi, 1930.

straight, its hardness, its peculiar cross-section, the ease with which it can be grown, a combination of useful traits found together in no other plant, bamboo is one of those providential developments in nature which, like the horse, the cow, wheat and cotton, have been indirectly responsible for man's own evolution. A tree which occupies so little space comparatively and demands so little attention, which attains its height in from thirty to sixty days only, the rate during the most rapid period of growth reaching sometimes as much as 90 centimeters in 24 hours, which again is so flexible and straight grained yet mechanically so perfect as to give satisfaction under the stress of all kinds of service, whose arching plumes finally under all conditions are so pleasing to the eyes—such a tree can not with all due respect to the coconut justifiably be given any but the première place of honor among all useful plants.



DR. HENRY NORRIS RUSSELL

RESEARCH PROFESSOR OF ASTRONOMY AND DIRECTOR OF THE OBSERVATORY AT PRINCETON
UNIVERSITY, ELECTED PRESIDENT OF THE AMERICAN ASSOCIATION.

THE PROGRESS OF SCIENCE

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE AT ATLANTIC CITY

UNDER the presidency of Professor John J. Abel, the ninety-first meeting of the American Association, together with thirty-nine associated scientific societies, convened at Atlantic City in the interval between Christmas and New Year's Day. It is the first time that the association has met at a resort city since the Saratoga meeting of 1879. Approval of the choice was shown by the fact that some fifteen hundred papers were read and that perhaps three times that number of people attended the sessions.

The general impression made by the Atlantic City meeting was most favorable. In addition to exceptionally good and well-organized section and society programs there were numerous and diversified symposia, bringing out the present state of our knowledge on many subjects, and a most excellent exhibit,

both scientific and commercial, supplementing the programs of papers and addresses. The popular lectures, too, were well selected and unusually interesting.

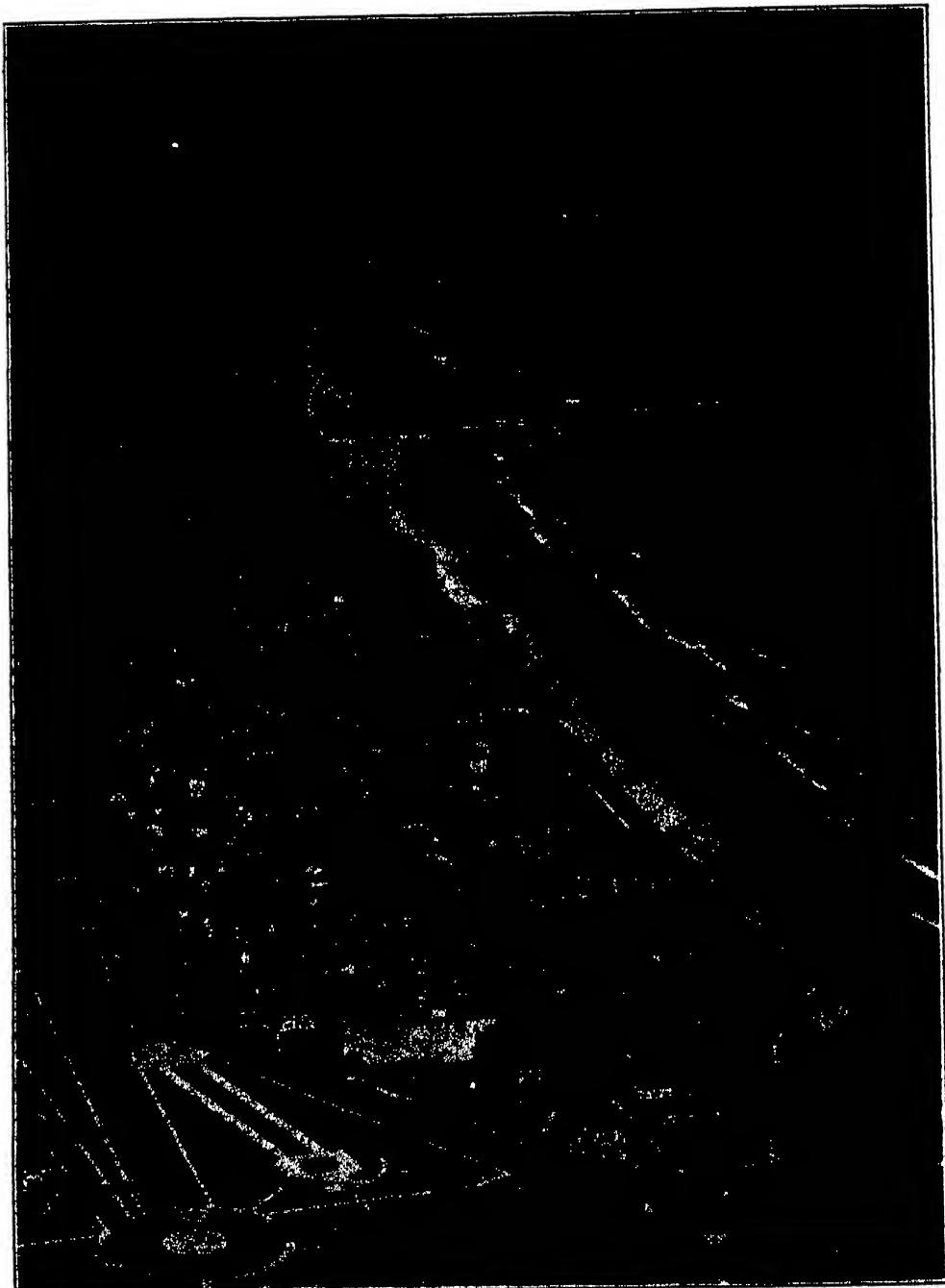
At the opening session, held in the ballroom of the Municipal Auditorium, Mr. A. H. Skean, the director of the Atlantic City Convention Bureau, welcomed the association to Atlantic City and Professor Luther Pfahler Eisenhart, dean of the faculty of Princeton University, to the State of New Jersey. Dr. Abel introduced the retiring president, Dr. Franz Boas, who addressed the meeting on "The Aims of Anthropological Research." On its conclusion a general reception was held in the Vernon Room of the Haddon Hall Hotel which was very well attended.

A feature of the program was the first Maiben lecture, given by Dr. Henry



THE BEACH AT ATLANTIC CITY

WITH THE BOARDWALK AND SOME OF THE HOTELS IN THE BACKGROUND.



—*Aero Service Corporation*

A PHOTOGRAPH OF ATLANTIC CITY FROM THE AIR
SHOWING THE MUNICIPAL AUDITORIUM, THE PIERS AND MANY OF THE HOTELS.



PROFESSOR JOHN J. ABEL

A PHOTOGRAPH OF THE PRESIDENT OF THE
ASSOCIATION TAKEN AT ATLANTIC CITY.

Norris Russell, of Princeton University, the new president of the association, who spoke on "The Constitution of the Stars." The Maiben lectures were established in memory of the late Hector Maiben, of Lincoln, Nebraska. These lectures will deal authoritatively with topics of active scientific interest on which the speaker possesses the right to an opinion by virtue of his personal work. They will, however, be designed for a general audience rather than for specialists.

From a program so diversified and so generally excellent as that arranged by the section and society secretaries, and by the permanent secretary of the association, for the Atlantic City meeting, it is with great hesitation that one selects items for special mention. Yet atten-

tion should be called to the fact that two of the symposia proved especially popular.

One of these was the symposium on the timely topic of stabilization of employment, which was discussed by fourteen of our leading authorities on economics, and the other was the symposium on cosmic rays in which Dr. Robert A. Millikan, Dr. Arthur H. Compton and others presented the latest results of their work.

Responsibility for the conduct of the affairs of the association rests mainly upon the shoulders of the permanent secretary. At the Atlantic City meeting Professor Henry Baldwin Ward was chosen for this important position. Professor Ward has long been connected with the association; in 1901 he was secretary of Section F (Zoology), in 1903 he was general secretary, and he was a vice-president in 1905. For a number of years he has been in the closest pos-



DR. HENRY B. WARD

PROFESSOR OF ZOOLOGY, UNIVERSITY OF ILLINOIS,
ELECTED PERMANENT SECRETARY OF THE ASSO-
CIATION.

sible touch with its affairs as a member of the Executive Committee of the Council.

Through our eyes we learn quite as much as through our ears. These two channels for acquiring information supplement each other, and through the joint use of both we lay a firm foundation for proper understanding. So in any well-balanced scientific meeting oral exposition of facts should, so far as possible, be supplemented by visual demonstrations.

The visual demonstrations supplementing the papers read at the Atlantic City meeting were provided by the science exhibition including no less than forty-seven units, many of these made up of several or even many different items.

Among the exhibits were artificially flattened human skulls from Venezuela, apparatus for the study of cosmic rays, living Surinam toads from Dutch Guiana, rare forms of matter, apparatus

developed for the measurement of photosynthesis as a function of wave-length and intensity of light, ultra-violet patterns on the wings of butterflies, samples of fish flour, fish meal and fish oil, apparatus for rearing blow-fly larvae for surgical use, a recently discovered map of the prehistoric Indian earthworks at the junction of the Muskingum and Ohio rivers, and many other items of equal interest.

In addition to these exhibits there were shown laboratory equipment and supplies of all descriptions, and an attempt was for the first time made to bring together for inspection all the scientific books of the calendar year.

More extensive and more varied than in any previous year the exhibits at Atlantic City were one of the outstanding features of the meeting. But the programs of the sections and societies were unusually full and interesting.

AUSTIN H. CLARK

THE PRESIDENT OF THE AMERICAN ASSOCIATION

DR. HENRY NORRIS RUSSELL, research professor of astronomy and director of the observatory at Princeton University, was elected president of the American Association for the Advancement of Science at the Atlantic City meetings.

Russell first attained general recognition by his work in the field of stellar constitution and evolution about 1913. Starting from Hertzsprung's differentiations of red stars into giants and dwarfs, he organized the luminosity-type diagram—which shows relations between intrinsic brightness and the surface temperatures of stars. He gave physical interpretation to this now well-known picture by following lines suggested many years before by H. Laue and Sir Norman Lockyer. Subsequent developments in atomic physics, which could not have been foreseen, have invalidated Russell's theory, but the diagram itself has exercised controlling influence on the advance of stellar phys-

ics. He has continued contributing to this now very complex subject, and in the first Maiben lecture at the latest meeting of the American Association for the Advancement of Science he presented a critical summary of current knowledge. He gave an earlier summary in a course of Lowell lectures in 1931.

Early in 1923, as the direct result of arranging demonstrations of spectra for an undergraduate course, he became interested in the expanding subject of the relation of spectra to atomic constitution. In collaboration with F. A. Saunders he attributed the anomalous terms in the spectra of the alkaline earths to the joint action of two electrons, initiating the interpretation of complex spectra. He has taken an extensive part in the analysis of such spectra. Another series of papers deals with astrophysical applications of these principles and of ionization theory, culminating in a study

of the composition of the sun's atmosphere (1929) and in studies of stellar spectra made in collaboration with W. S. Adams and Miss Moore.

In positional and dynamic astronomy, mention may be made of his work on stellar parallax (published 1911); on the photographic determination of the moon's place; and on dynamical parallaxes of double stars--the latest list by

Russell and Miss Moore includes 1,777 objects. Photometric interests are represented by a discussion of the albedo of the planets and satellites (1916) and a series of papers on the determination of the elements of eclipsing variables (partly in collaboration with Shapley, then a graduate student). His war-work on airplane navigation also may be mentioned.

J. Q. S.

THERMODYNAMICS AND THE RELATIVITY THEORY

DELIVERING the Josiah Willard Gibbs lecture before the American Mathematical Society and the American Association at Atlantic City on December 29, Professor Richard C. Tolman extended thermodynamics to Einstein's special and general theories of relativity. According to an abstract prepared by *Science Service* he arrived at findings that promise to have profound influence on philosophy and even religion as well as on science.

Old-fashioned, classical science viewed the universe as running down in energy like a clock, eventually dying a "heat-death" when all heat and energy arrives at a dead level. Professor Tolman's greatly simplified cosmological models hold the hope that under the new relativistic thermodynamics the universe can forever and ever experience a succession of irreversible expansions and contractions.

This fits in with the astronomical observations that we live in a rapidly expanding universe in which the great stellar galaxies are rushing away from us at speeds of thousands of miles a second. Professor Tolman's tentative idea of the universe explains how it is possible that it is now expanding, that it previously contracted, that it will contract in the future and that this cycle will continue unendingly.

A creation or beginning of the universe is necessary under our ordinary, every-day, classical ideas. Professor Tolman's marrying of thermodynamics with relativity may have removed the

necessity of thinking of the universe having a beginning. In the "cautious position" to which he is taken by his mathematics and physics, "we no longer dogmatically assert that the principles of thermodynamics necessarily require a universe created at a finite time in the past."

Gibbs was the great American scientist who gave the classical principles of thermodynamics their most complete and comprehensive expression. Delivering a memorial lecture named in Gibbs's honor, Professor Tolman told why it has become necessary to extend the classical thermodynamical principles to relativity that has so greatly influenced all science in the last two decades.

Classical thermodynamics was developed with the assumption that the things about him were at rest with respect to the observer. Professor Tolman found it necessary to develop thermodynamics for observers in uniform relative motion to each other as is the case in the Einstein special theory of relativity.

The old-fashioned thermodynamics applied to space and time that had limited range and lacked strong gravitational fields. Professor Tolman found it necessary therefore to extend thermodynamics to Einstein's general relativity in order to consider the heat-energy behavior of large portions of the universe. The older ideas of heat and energy needed refining in just the same way that Einstein found it necessary to develop a theory of gravitation that is more precise than Newton's.



WILLIAM JACOB HOLLAND

THE DISTINGUISHED NATURALIST WHO DIED ON DECEMBER 13 AT THE AGE OF EIGHTY-FOUR YEARS.

REMINISCENCES OF A NATURALIST

EIGHT days before his death Dr. William J. Holland, for thirty-four years director and director emeritus of the Carnegie Museum, Pittsburgh, wrote the following letter to Mr. F. Dale Portine, of Columbus, Ohio:

Your letter of December 4 has just been received. Some day or other, if life is spared to me, I hope to be able to write an autobiography, in which I certainly shall have occasion to tell many an amusing story about bugs, bones, and big-wigs. Your request to let you have a little chapter out of that autobiography, in order to include it in the paper which you tell me you intend to present, "stirs up my pure mind by way of remembrance."

You ask me the reason why I like nature-study. I will endeavor to be brief.

My love of nature is, I think, inherited. My mother's father was an amateur botanist of more than ordinary ability, the friend and correspondent of Shortt, Torrey, Mead, Darlington, Asa Gray, and a host of others. The herbarium he made is now deposited in the Carnegie Museum and is my property. It is large and rich in specimens labelled by the fathers of American botany. My father's father was a florist, and also an amateur botanist, in North Carolina. He built the first greenhouse erected in that State. My father was deeply interested in natural history from his boyhood. He went as a missionary to the West Indies, and there made a large collection of dried plants and of shells. On a furlough to the United States he took his plants to Bethlehem, Pennsylvania, to endeavor to have them determined, in part at least, by my mother's father. He there met my mother, they fell in love with each other, and were married. I am the child, therefore, of a botanical alliance. When my parents went back to the mission station in the West Indies they went on with their work of collecting. My father's house was the resort in Jamaica of visiting naturalists. Such men as P. H. Gosse, and C. B. Adams stayed for longer or shorter periods under the roof. C. B. Adams, who was the State Geologist of Massachusetts, and who with my father's help made a great collection of the shells of Jamaica, rocked my cradle. Of course I do not remember that fact, but I have been told so. Adams was professor at Amherst College, and it was because of my father's admiration for Adams that I long afterwards was sent to Amherst.

When my parents left the island of Jamaica, owing to my mother's ill health, my father be-

came the pastor of a Moravian Church first at Dover and then at Sharon near Tuscarawas, Tuscarawas County, Ohio. My earliest recollections as a child are of being permitted, as a reward for good behavior, to look at the cabinet of shells, to carefully open and study the boxes of butterflies and beetles which my father had brought from the West Indies, and, a little later, I was set to work to collect land-shells and flowers about Tuscarawas in your own State of Ohio. My father taught me the scientific names of the plants and of the shells before I even knew their common English names. When I was a child of eight I knew that white clover was *Trifolium repens*, that the bluebird is *Sialis sialis*, etc. I can never forget my Ohio days. I can still see the nests of the red-winged blackbird among the wild roses in the swampy meadow before our house. I remember the meadow-lark which lured me from her nest in the grass by feigning to be crippled, and then flew away and gleefully chanted her delight. I can still see the toads spawning in the brook. Many strings of sunfish I caught in the Ohio Canal and many a channel-catfish (some of them big ones) I caught on my out-lines which I set just below the State Dam on the Tuscarawas River.

When the family removed in 1858 (I being a boy of ten) to western North Carolina, I kept up my collecting. I had there at my command a copy of Wilson's Ornithology with Bonaparte's Supplement in four volumes; I had the first edition of Say's Entomology; and some others of these old and now little consulted books. I dug into them *con amore*. I knew all the birds' nests within a mile and a half of the village of Salem, now Winston-Salem. I reared butterflies and moths from the larvæ by the hundreds; I collected everything that I could lay my hands upon, and, though all but the botanical specimens ultimately were destroyed, I made what was really, as I recall it, a very considerable collection of insects, many of them representing species which were not named and described until a later date by such men as Grote, Le Conte, and Horn. These collections were left behind in 1863 when I came north with my parents by an underground route full of adventure. I was sent to college first at Bethlehem, then Amherst. I kept up my botanical collecting, but the insects were not pursued until after I had become settled in the pastorate of a church in Pittsburgh. Then I reverted to my early entomological love and I did not pursue my studies in a desultory way, but I resolved to master the subject. The literature of entomology was not accessible in Pittsburgh in the late seventies and early

eighties, so I began to buy books and I have spent tens of thousands of dollars in acquiring practically all the literature relating to the lepidoptera in whatever language written. I employed men to collect for me, not only in the United States, but in many foreign countries. I was the first patron of the late William Doherty who collected for me in the Himalayas, in Siam, in the various islands of the Malay Archipelago, in New Guinea and the Philippines, and at the close of his life in Uganda, Eastern Africa. I collected, myself, everywhere I went, and made large collections in Japan, where I was the naturalist of the United States Eclipse Expedition in 1887; I have bought many classical collections, among them the great collection of William H. Edwards, upon which was founded his great work in three volumes upon the butterflies of North America; I bought the collection of Mr. Theodore L. Need containing the lepidopteras collected by the Wheeler Expedition to the Rocky Mountains in connection with the survey for a trans-continental railway; I bought a score of larger or smaller European collections; my collections of African lepidoptera, which are particularly rich, were made for me by missionaries to tropical West Africa who received their training as students in the Theological Seminary in Pittsburgh, of which I am now the Senior Trustee.

But I am running away from your question. I believe it was Pope who said of himself: "I lisped in numbers for the numbers came." He was a "born poet," so I may say of myself that I am a "born naturalist." I love not merely to investigate and study the details of an insect, but in its broader outlines I love the study of nature in all of her ever-varying aspects. I have devoted a great deal of time to reading along the lines of physics and especially astronomy. In fact just after my graduation at Amherst I was offered a position as instructor in chemistry and physics at Robert College in Constantinople, but my father dissuaded me from accepting the post, because he wished me to go on in this country with my professional studies. I am personally acquainted with most of the leading astronomers

of the world. Professor Langley was a dear friend and associate of mine, both before and after the time when I became the head of the University of Pittsburgh, and I was an eye-witness of many of those experiments which he made to determine the laws governing flight. So you see I have lived all my life in contact with biologists, physicists, and astronomers, and it would be very queer, indeed, if I were not an enthusiast along the lines of nature-study. For twenty-five years I have been a student of paleontology. I had studied paleontology as a boy at Amherst. When Mr. Carnegie induced me to take charge of the development of the great Museum which bears his name, he urged me to lay stress upon paleontology and told me he stood ready to furnish all the needed funds. The result has been the discovery of a vast quantity of wonderful material in the fossil quarries of our western country and among them complete skeletons of a number of huge dinosaurs. At Mr. Carnegie's request and at his expense I had the fun of setting up replicas of the dinosaur *diplodocus* in many of the national museums of Europe, and elsewhere, on which occasions I had the pleasure of making the acquaintance not only of the scientific men of the countries, which I visited, but of their sovereigns. I have "stood before kings" and emperors, many of whom have in recent years lost their "jobs," or in the case of the Czar have been murdered. I could tell you many interesting and amusing things about these people, but you have tempted me to write quite too long a letter. I came to be a nature-lover because two generations before me were nature-lovers and the disease, if you choose to so call it, was in my blood.

My motive in writing *The Butterfly Book*, *The Moth Book*, and *The Insect Guide* was to help the young people of this generation, and to keep them from having to toil, as I had to toil as a boy, to find out something about the names and classification of the insects, which I collected.

Now, I think I have said enough, and if there is anything in this screed which you can use in your address you are at liberty to do so.

THE SCIENTIFIC MONTHLY

MARCH, 1933

The Scientific Work of the Government of the United States

SCIENCE IN THE DEPARTMENT OF COMMERCE

By Secretary ROY D. CHAPIN

U. S. DEPARTMENT OF COMMERCE

IN many ways it is the business of the United States Department of Commerce to bring science and technology to the aid of world-wide commerce by services both regulatory and promotive. The five bureaus which regulate are chiefly of long standing; the promotive functions were largely evolved during the present century. The regulatory functions apply known technical data, while the promotive functions blaze new trails through research.

Commerce and science are closely related. At the dawn of history men used stars as guides on the sea or across the desert. Commerce ramifies to the ends of the earth and to all science and technology to serve and be served. When in untrod lands explorers display novel wares to new peoples for diplomatic barter, commerce begins. It follows close on the heels of the explorer. Those who visited foreign ports became close observers of natural phenomena and thus acquired travel lore and some knowledge of astronomy and meteorology.

Science was called to aid, for trade routes must be safe and sure. We can not entrust rich argosies of commerce to uncharted seas exposed to unknown perils. It is, therefore, natural that cer-

tain federal scientific bureaus are found in the Department of Commerce.

The magnetic needle guides navigation, but it is not enough to have a compass. Its deviation from true north must be known, for the needle is not "true to the pole." Its deviations change with place and time. The laws of change must be known. Hence experts of the Coast and Geodetic Survey measure and chart daily, seasonal, long-term and abrupt changes in the deviation of compass north from true north. The Survey, founded in 1807, and the oldest scientific bureau in the government, is the Department's unit for precise survey of our domain and its coastal waters. Its transcontinental arcs, level network and tidal datum planes, unexcelled for precision, give the national basis for location of places and routes of commerce. Charts of waterways show depths, shallows, reefs and submerged wrecks, giving navigation safe channels. Some 700 charts are maintained and published by the Survey. Of these, 286,000 were sold in a single year. Ninety-two airways maps cover the entire country, and strip maps are printed in convenient form for air pilots.

The tides are factors in commerce.



—Underwood and Underwood, Washington, D. C.
ROY D. CHAPIN
SECRETARY OF THE DEPARTMENT OF COMMERCE.

The Survey gathers data from automatic tide records, adds astronomical and meteorological rhythms and computes tides for the leading ports of the world. Its tide-predicting machine—a masterful invention of departmental experts—computes automatically what would otherwise require forty trained computers. The resulting tide tables have a world-wide circulation, aiding commerce, which must observe time and tide, which wait for no man.

The Survey's earthquake records aid the selection of sites for construction, and its data on refined geodetic surveys enable its experts to compute the shape of the earth, its dimensions and changing levels by which "isostasy" adjusts the crustal masses of the earth to equate their pressure distribution. Thus the earth, the stage of the drama of commerce, is the basic interest of a great unit of the Department.

Closely linked with some of the activities of the Coast and Geodetic Survey, and, in fact, growing out of them, is the work of another scientific unit of the Department—the Bureau of Standards.

Uniform standards are absolute essentials of commerce. Without standards of measurement, quality, performance and practise, hopeless confusion would result and trade would come to a standstill. Less than 30 years after the establishment of the Coast Survey, its office of standard weights and measures was distributing uniform standards of length, mass and capacity to the federal custom houses and to the state governments to the end that commerce with foreign nations and within the United States might be on a uniform basis. By act of Congress in 1901 the functions of this office were enlarged and its name changed to the Bureau of Standards. It was authorized to assist the government, industry and individuals in all matters pertaining to standardization. It is the custodian of our national standards of length and mass, and, using these as a

basis, constructs multiples and subdivisions, and derives standards for every kind of measurement. It develops standards in new fields, such as radio and x-rays, and improves existing standards to keep pace with industrial developments. It sets up standards of quality for many of the articles of commerce and establishes standards of performance for many of the machines by which commerce is carried on, as the internal combustion engine; and draws up standards of practise to safeguard workers from the hazards which commerce brings in its train, as in the generation, distribution and utilization of electrical energy.

In its development and improvement of standards, the Bureau cooperates with almost every industry. Its investigations lead to better and cheaper products and improved service with conservation of lives and natural resources. It aids directly the manufacturer, distributor and consumer by pointing the way to possible reductions in the sizes and varieties of articles in common use, and by promoting uniform standards of quality.

The Bureau acts as the principal research and testing laboratory of the federal government, and has helped to place governmental purchasing on a scientific basis. It assists in the preparation of specifications which simplify the commercial transactions between the government and industry. It is, likewise, a clearing house for all matters of standardization affecting the United States and other nations, and in this way is helping to place the standards essential to world commerce on a basis of international uniformity.

It is obvious, then, that over land, sea and air commerce is entering a new era in which science looms large. Profiles of aircraft are streamlined in laboratory wind tunnels. Unanticipated speeds span our continent in less than half a day. Radio waves keep aircraft "on



BUILDING OF THE DEPARTMENT OF COMMERCE

course" in continual touch with base, so that dead-reckoning hazards vanish.

Scores of aids to navigation are maintained by the departmental units to perfect transport by land, sea and air. What is true of navigation is true of other factors affecting commerce. Weights and measures ensure equity in trade. The yields of mines and fisheries are increased and improved, as commerce, through research on extraction and production, improves products and processes. It is to-day fair to say that success in commercial enterprise rests on the intelligent use of data placed in the hands of the business man by the scientific man.

Commerce is promoted most directly by a special unit of the Department—the Bureau of Foreign and Domestic Commerce. Its economists and technicians on the firing line of business crusading are alert in forecasting trade conditions and opportunities. Statistics from a world-wide front reveal latent factors in success which have helped to make our country a leader in foreign trade. This unit promotes domestic trade as well. The exigencies vary with time and place and must be taken into account. This calls for studies in the psychology of peoples, their social controls, customs and specific needs.

The laws of trade may yet be formulated in a new technology in which standards and measurements of quality, quantity, value, place and time—the five coordinates of commerce—may be effectively correlated. This may even flatten the curve of the business cycle, making prosperity continuous rather than occasional. Until then the program of the Department is to give all business men dependable knowledge of the best business experience and judgment of our time.

On land, obstacles are easily seen. On the water, hazards may be hidden. To maintain aids to safe and sure navigation of water or air is the function of the

department's unit, the Bureau of Lighthouses. On a homebound ship we determine position by radio beacon signals from numerous stations along our shores. Next we may pick up a lightship, a floating lighthouse moored perhaps twenty miles off shore. Next appears one of the great first-order lights with its million-candlepower beam to mark outer promontories or obstructions of the coast. Then appear the smaller second-order or third-order lights within the bay, and, lastly, buoys marking the channel to safe harbor. The aids to navigation provided by this Bureau call for ingenuity and technical knowledge both in the design and in the maintenance of uninterrupted service. An important recent aid maintained by the Bureau of Lighthouses is the airways beacon, visual and radio. These indicate to an air pilot whether he is on or off course in dark or fog, and if off course how he must fly to get back on course again. This unit in many ways renders a fundamental service to commerce, promoting speed, safety and precision in navigation.

The safety of all who "go down to the sea in ships" is the concern of the Department's navigation and steamboat inspection unit. Water-borne commerce on steam vessels includes three hundred million passengers a year. Their safety is assured by trained inspectors, who quietly and unobtrusively safeguard life and property from the perils of defective equipment and operation—perils as real as those of the sea. Science and technology are involved.

With every precaution private owners can take, accidents do occur. Hence systematic regulation and inspection are imperative. A boiler explosion or a fire is far more serious at sea than on land. Hence boilers, fire-detecting, fire-fighting, life-saving and steering apparatus are regularly inspected. With government supervision accidents are far less frequent. Boiler material is tested at

the mills, boilers are examined under construction, and tested when completed, their safe working pressures being computed. Inspection of vessels begins when the keel is laid and continues during construction.

Simple rules of safety apply even to small motor boats, of which several hundred thousand ply on navigable waters and must register with the Department of Commerce under the law. These rules are enforced by the Bureau of Navigation and Steamboat Inspection. Vessels of our merchant marine are inspected annually and certified for a year if found seaworthy. Excursion and ferry steamers are inspected more often. In these and other ways this important unit affecting safety on our waterways is actively reducing accidents by removing the hazards which cause them. In modern times safety is a problem of technology which finds its basis in the science of materials, devices and processes.

Air commerce is modern. When commerce took to the air new problems arose—some administrative, some highly technical and calling for experimental research. The Aeronautics Branch of the Department is charged with the subject of commercial aeronautics. Airplanes and pilots are examined. If the aircraft act is violated, a fine or revocation of license follows. For the Aeronautics Branch, aircraft motors are tested by experts of the Bureau of Standards. If found airworthy they are accorded the Department's airworthiness certificate. Mapping the airways is the work of the Coast and Geodetic Survey; aids to air navigation are provided by the Lighthouse Service; research is assigned to the Bureau of Standards; and cooperating committees report on outstanding problems.

Recent achievements are the system of plane-to-ground telephony and the systems of multiple radio ranges designed to serve as airways in fog or darkness.

A truly sensational possibility is the system of blind landing devised by Bureau of Standards experts in cooperation with the Aeronautics Branch. This points to navigation of the air by automatic control. Much research and field work remains to be done, but the trail is blazed toward perfected built-in controls which may yet eliminate the hazard of human pilotage.

The fisheries industry has been notably aided by the Department's Bureau of Fisheries. The arts of quick freezing, efficient packaging and the recognition of the food values of sea food in combating faulty nutrition are making fishery products more popular with the consuming public. The industry, however, suffers from certain natural handicaps, such as the distance of the sources of supply from centers of population, the seasonal nature of the catch and the uncertainty of its volume, so that research must be continued if fishing is to maintain its important industrial position.

The Bureau conserves the supply of food fishes by taking measures to prevent pollution of lakes, rivers, small streams and coastal waters by manufacturing or populous centers. It also aims to keep sources well stocked with fish. On the initiative of the Department, Congress authorized research on fish diseases, a subject vital to public health and to our edible fish supply.

International cooperation is essential to conservation. The Department is concerned with the project of the League of Nations to conserve those species of whale which are still sufficiently numerous to form an important industry. Certain species almost wiped out will become extinct unless the industry is regulated. A well-known project protects the fur seal in the North Pacific. The nations concerned have saved the fur-seal herd which breeds on the Pribilof Islands in Bering Sea. Once threatened with extinction, the herd is now a gain-

ful flourishing economic resource. Under 21 years of the international treaty the herd has steadily grown until now 50,000 surplus 3-year old male seals are taken annually. Similar protection is afforded foxes on the St. Paul and St. George Islands, and sea otters, sea lions and walruses.

Technical studies yield valuable data for the fishing industry. The life habits of fish and the changes in the abundance of various kinds of fish are studied. An efficient fish ladder for the upstream migrations of the salmon and other fish was developed in cooperation with the states and the industry. The Bureau's aid to the pearl button and goldfish industries will long be remembered.

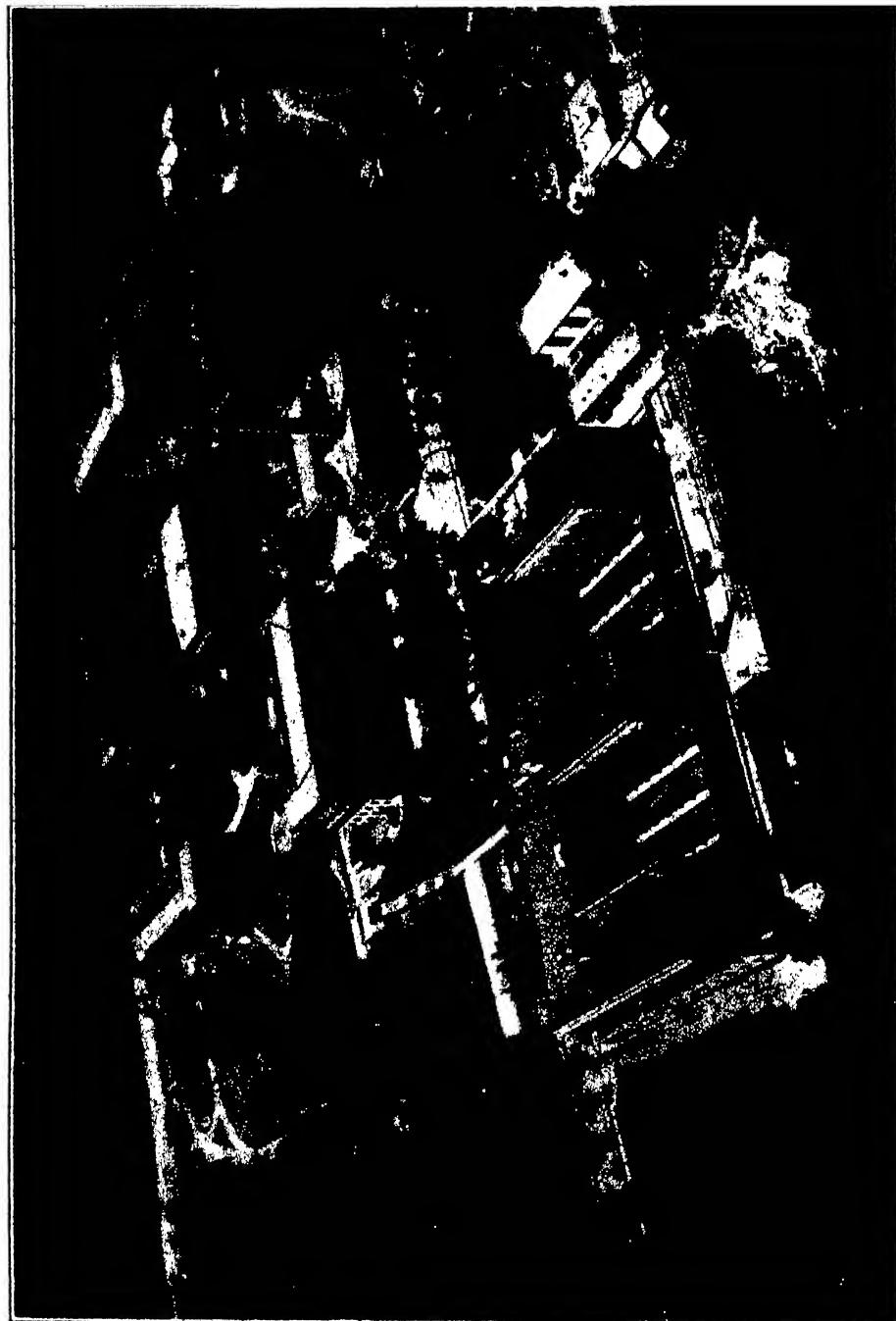
Mine products bulk large in commerce. The Department's unit dedicated to this great industry, the Bureau of Mines, conserves mineral wealth, reduces waste in the mineral industries and helps to make these industries safe and healthy for miners. Its administrative, technologic, economic, safety and health services are widely known and appreciated. Its scientific research on helium brought this once rare gas from the laboratory into commerce, with an annual production of 24,000,000 cubic feet for use in giant airships. New methods devised by the Bureau save millions in metal losses. Its technical studies cover such varied subjects as electric smelting, lead and zinc wastes, the physics and chemistry of steel making, the flotation of zinc, the recovery of lead and copper by leaching from oxidized ores, and the recovery of precious metals.

The Bureau of Mines has an experimental blast furnace (the only one of its kind) for the detailed study of temperature distribution, furnace gas composition and the moving charge. It has shown how to reduce operating costs. The Bureau is a potent factor in advanc-

ing the mining industry and its bulletins are appreciated sources of dependable data for commercial enterprise in the mining field.

Our national life—its activities and possessions—is gaged by the census unit of the Department of Commerce. Great volumes result, data which guide alike business and statecraft in meeting changing conditions in industry and commerce. Since 1790 the Census has steadily developed in scope of subject, area of domain covered, in its precise formulation of results and in the efficient means for computing their sums and relations. These statistical harvests provide for commerce a measure of sources and markets. Starting with its house-to-house mission reaching every home, the Bureau of the Census resorts finally to automatic high-speed machines which classify and integrate the vast volumes of data as a basis for the sociologist, the economist and the historian in their scientific researches on our national life.

Inventions multiply the articles of commerce and the mechanisms which it uses. They profoundly affect human life—aid its well-being, add comforts and luxuries once undreamed of. To stimulate invention Congress set up the Patent Office, to assure inventors property rights for a period. Technicians study the inventor's claims and allow only those that are novel so that the monopoly allowed is equitable. Science enters the work of this unit, for the inventor's claims often involve highly technical problems in physics and chemistry. Patent files are a notable source of technical history, and its claim correspondence is rich in technical discussion of the state of the arts. Fifty thousand new inventions a year have an effect on our civilization which can not be visualized, ramifying to the minutest details of our industrial régime.



AIRPLANE VIEW OF THE BUILDINGS OF THE BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

By the Late Dr. GEORGE K. BURGESS¹

DIRECTOR OF THE NATIONAL BUREAU OF STANDARDS, 1923-1932

MEASUREMENTS to-day play a leading rôle in human progress, and their range, precision, variety and uses multiply incredibly. Experts themselves hardly realize how fully this ancient art of measurement has become the peerless tool of discovery, record and control in science and industry. Measurement is recreating industry through enhanced accuracy at all points and more facile measuring methods which tend to become automatic. The procedure which measures a thing may be turned back to control its magnitude. Energy equivalent to that of a fly may regulate thousands of horsepower. Furnace heat is measurable and if we have a unit, a standard, a method and a measuring device we may also control that furnace heat. The sum of such automatic controls assures the quality of a product or its accuracy. Effective measurements set up by research replace empirical judgments and become standards of practice to control industrial processes.

Standard weights and measures are as old as civilization. Standards are true autocrats, with a domain as broad as human activity. They ensure justice and accuracy, matters so important that to maintain the standards is a basic function of the central government. The Great Charter mentions them and our Federal Constitution gave Congress power to "fix the Standard of Weights and Measures."

Standards must be applied to be of service to man. They are not mere in-

¹ This posthumous article was the last written by Dr. Burgess. On July 2, 1932, he was stricken at his post and died without regaining consciousness. It is most fitting that his last writing should be an introduction to a series of articles on the institution to which he had devoted the best years of his life with such outstanding success.

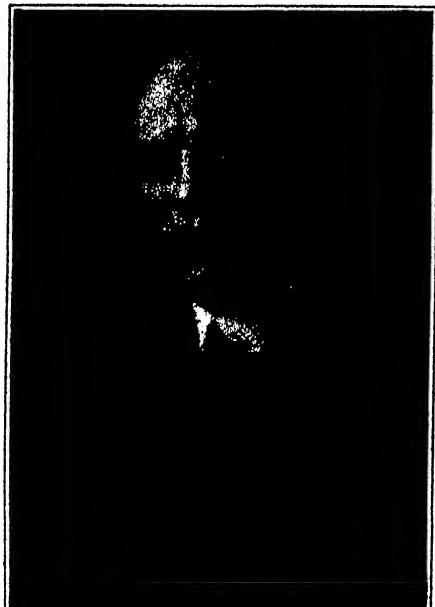
ert relies deposited in a vault but are actively functioning as process controls of industry, affecting every detail of manufacturing operations and products. Measurements embodied in standards of size, quality or performance thus become supervisory of the complex of motions and conditions which we call industry. By research we may determine experimentally the best magnitudes—safe minima, attainable maxima, economic optima. What mixture of air and gas gives most car miles? The answer becomes a standard for engine designers in promoting progress for tank, boat, car, airship and airplane. A thousand industries need such basic data upon which to build progress. This is one purpose of our National Bureau of Standards.

The Bureau was founded as a research laboratory to develop, construct and maintain the reference and working standards, and to intercompare, improve and apply them in every field in which they are used. Its activities in research and standardization make a narrative of impressive interest in pure and applied science. The Bureau, besides furnishing the standard basis of measurements for the countless transactions of daily trade, also conducts hundreds of researches of vital concern to science, industry and commerce. It encourages industry to eliminate needless varieties and sizes of products and to standardize their quality by national specifications. In the interest of pure and applied science, its work ranges from measuring the heat of a star to things as practical as paving brick, as subtle as the earth's magnetic field or infinitesimal as the force in a single atom. The same instrument which measured the surface tem-



SAMUEL WESLEY STRATTON

THE FIRST DIRECTOR OF THE NATIONAL BUREAU OF STANDARDS, WHO SERVED FROM 1901 TO 1923 WHEN HE BECAME PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY. HE DIED IN 1931.



GEORGE KIMBALL BURGESS

DIRECTOR OF THE NATIONAL BUREAU OF STANDARDS FROM 1923 UNTIL HIS DEATH LAST SUMMER.

perature of Mars is now being used to study combustion in an engine cylinder.

The strength of the Bureau's work is in its joint attack on complex problems from many salients in scores of specialties by experts picked by merit, trained intensively in narrow fields, working in contact with the seventy specialized fields of Bureau work. Such training has developed many leaders who have left the Bureau to direct industrial research laboratories and testing stations or remained to head various divisions and sections, since lines of advancement are



LYMAN J. BRIGGS

ACTING DIRECTOR OF THE NATIONAL BUREAU OF STANDARDS AND CHIEF OF THE DIVISION OF MECHANICS AND SOUND.

open to the highest positions in the Bureau. The section is the unit of specialization, 70 in all, each headed by an expert uniquely equipped with staff, facilities, quarters, literature and a tradition for effective work. Each section must acquire also the techniques, contacts and specialized knowledge so essential to its work.

The leading founders of our government appreciated the importance of ex-

FUNCTIONS

DEVELOPMENT, CONSTRUCTION, CUSTODY, AND MAINTENANCE OF REFERENCE AND WORKING STANDARDS
AND
THEIR INTERCOMPARISON, IMPROVEMENT, AND APPLICATION IN SCIENCE, ENGINEERING, INDUSTRY, AND COMMERCE

STANDARDS

1

STANDARDS OF MEASUREMENT.

Reference and working standards for measurements of all kinds, including fundamental and derived **STANDARDS OF MEASUREMENT** for expressing the quantitative aspects of space, time, matter, energy, and motion, and of their interrelations.

By definition, specifications, or material standard, covering, for example, length, area, and volume; mass, weight, density, and pressure; heat, light, electricity, and radioactivity, including for each the quantity, rate, intensity, density, etc.

2

STANDARD CONSTANTS.

Natural standards or the measured numerical data as to materials and energy known as physical or **STANDARD CONSTANTS**—the fixed points or quantities which underlie scientific research and industrial processes when scientifically organized.

Mechanical equivalent of heat, light, electricity, and gravitation; specific densities, viscosity, melting and boiling points; heat capacity, heats of combustion; velocity of propagation of light; conductivities of materials to heat and light; electromagnetism and atomic weights; and many similar magnitudes determined experimentally with maximum precision and referred to fundamental standards of measure.

3

STANDARDS OF QUALITY.

Specifications for material (by description, sample or book), known as **STANDARDS OF QUALITY**, being in measurable terms a property or group of properties which determine the quality.

The numerical magnitudes of such conditional property pertinent to the quality involved and specific magnitudes in units of measure of such significant factors as uniformity, composition, form, structure, and others.

4

STANDARDS OF PERFORMANCE.

Specification of operative efficiency or action for machines and devices, known as **STANDARDS OF PERFORMANCE**, specifying the factors involved in terms susceptible of measurement.

Precise statements of speed, uniformity, output, economy, durability, and other factors which together define the net efficiency of an apparatus or machine.

5

STANDARDS OF PRACTICE.

Codes and regulations impartially analyzed and formulated after study and experiment into **STANDARDS OF PRACTICE** for technical regulation of construction, installation, and operation, and based upon standards of measurement, quality, and performance.

Statements of standard data, numerical magnitudes, and ranges of the pertinent factors defining quality, safety, economy, convenience, and efficiency.

THE FUNCTIONS OF THE BUREAU OF STANDARDS

act and uniform standards, yet action was slow. Washington held it an obligation that standards be provided. Jefferson, a student of the subject, when Secretary of the Treasury recommended (1790) that standards be adopted. President Madison (1817) reminded Congress of its failure to establish standards. Finally, John Quincy Adams, Secretary of State, after four years of research, made (1821) a brilliant report on weights and measures, which is still a classic. In it he proposed an international conference to establish a universal and uniform system.

Although, at the early period we are considering, some confusion in commercial transactions might be overlooked,

PURPOSE

To AID ACCURACY IN INDUSTRY through uniform and correct measures;
To ASSIST COMMERCE in size STANDARDIZATION of containers and products;
To PROMOTE JUSTICE in DAILY TRADE through systematic inspection and regulation;

To FACILITATE PRECISION IN SCIENCE and TECHNOLOGIC RESEARCH through calibration of units, measures, and instruments involved.

To SERVE as an EXACT BASIS for scientific study, experiment, competition, and design;

To FURNISH an EFFICIENT CONTROL for industrial processes in securing reproducible and uniformly high quality in output;

To SECURE UNIFORMITY OF PRACTICE in graduating measuring instruments, or in compiling tables for standards of quality and performance, and wherever such uniformity is desirable;

To AID LABORATORY RESEARCH BY REDUCING ERRORS and uncertainty caused by use of data of doubtful accuracy

To SECURE HIGH UTILITY in the PRODUCTS of industry by setting an established standard of quality;

To FURNISH a SCIENTIFIC BASIS for FAIR DEALING to avoid disputes over differences;

To PROMOTE TRUTHFUL BRANDING and ADVERTISING by suitable standards and methods of test;

To PROMOTE PRACTITION and AVOID WASTE in science and industry by enforcing quality standards by which materials may be made, sold, and tested.

To CLARIFY THE UNDERSTANDING between maker, seller, buyer, and user as to operative efficiency of appliances and machines;

To MAKE EXACT KNOWLEDGE THE BASIS of the buyer's choice;

To STIMULATE AND MEASURE MECHANICAL PROGRESS.

To FURNISH for each utility a single IMPERSONAL STANDARD of practice as a BASIS FOR AGREEMENT of all interests, clearly defined in measurable terms;

To INSURE EFFECTIVE DESIGN and INSTALLATION of utilities of all kinds;

To PROMOTE SAFETY, EFFICIENCY and CONVENIENCE in the MAINTENANCE and OPERATION of such utilities;

To SECURE UNIFORMITY OF PRACTICE where such is practicable, and EFFECTIVE ALTERNATES in other cases.

uncertainty in regard to the coinage could not be tolerated. Congress (1828) directed that a brass troy pound weight, secured by our minister in London in 1827, should henceforth be used as the standard for coinage. This troy pound was deposited at the Mint in Philadelphia and besides regulating the coinage it virtually became the fundamental standard of the United States, from which the avoirdupois pound was derived. It remained as our standard for coinage until Congress directed (1911) that the "standard troy pound of the Bureau of Standards" should be used for this purpose.

The Secretary of the Treasury was directed by Congress (1830) to verify the

weights and measures of the customs houses, and serious discrepancies were found. As the Constitution requires that "all duties, imposts, and excises shall be uniform throughout the United States," Congress directed the Treasury (1836) to adopt and construct uniform standards and send accurate duplicates to each custom house and to each state government.

Meantime the Treasury began a survey of our coast, having secured a leading metrologist of his day—F. R. Hassles, a Swiss,—to head the work. He brought with him English standards and made up sets based on these, thus fixing our "customary system of weights and measures." A set of the new standards was sent to each custom-house and to each state government. Curiously, nothing was said as to their use, and pertinent federal legislation is still lacking. The standards did, however, aid in securing fair uniformity among the states.

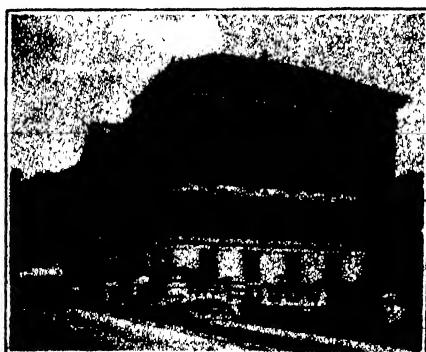
The metric system was made legal throughout the United States for all purposes by Act of Congress (1866), and sets of the metric standards were sent to the States by the Treasury Department. Fifty years after Adams' proposal, delegates from fifteen nations met in Paris (1870) to establish uniform standards for the world, and although the Franco-Prussian War interrupted the sessions, they were resumed two years later, with delegates from thirty



INDUSTRIAL LABORATORY

nations in attendance. The resulting treaty (1875) established three new agencies: (1) The International Conference on Weights and Measures; (2) The International Committee on Weights and Measures; (3) The International Bureau of Weights and Measures located on neutral territory near Paris. Together they form a world tribunal of highest resort in matters of weights and measures.

The first treaty obligation (1875) was to construct new standards of the meter and kilogram, that is, standards of length and mass. Sixteen commissions planned the technical details and fourteen years later (1889), the task completed, accurate duplicates (national prototypes) were deposited with each supporting nation (now 32 in all). President Harrison (1890) witnessed the breaking of the seals of the American prototypes now preserved in the Standards Vault of the National Bureau of Standards. These constituted a great achievement, meeting the most exacting demands of metrology. An order (1893) issued by the Superintendent of Weights and Measures, approved by Secretary of the Treasury



CHEMISTRY BUILDING



SOUTH LABORATORY

Carlisle, therefore made the new metric prototypes fundamental for all units of length and mass and their derivatives, the yard and pound being derived from the meter and kilogram by relations fixed by the act of Congress in 1866.

Thus were adopted our present national standards of length and mass. Such basic standardization was almost the only work of the old Office of Standard Weights and Measures and in its activities derived and working standards, such as are now essentials of industry, had little place. Some other nations were far in advance of us in this respect.

Germany (1868) organized its Normal Aichungs Kommission to regulate weights and measures and (1887) founded the Physikalisch-Technische Reichsanstalt—a national physical laboratory for research and standardization. Great Britain (1879) set up a Standards Department in its Board of Trade to construct and verify copies of standard weights and measures, an Electrical Standardizing Laboratory (1890) and a National Physical Laboratory (1899). Other nations, inspired by the pioneer laboratory (The International Bureau of Weights and Measures) have since established similar institutions.

About 1900 the demand for exact

standards in this country became insistent. The value of accuracy was recognized, science contributing much to make such accuracy possible in industry. An age of precision had set in, and leading men of science and industry urged Congress to establish a National Bureau of Standards. On behalf of the International Electrical Conference at Philadelphia (1884) Snyder and Rowland urged through the State Department that a Bureau of Physical Standards be established in Washington. A decade later A. G. Webster urged similar action. After extended hearings (1900) a bill passed by Congress was approved by President McKinley (1901) which begins: "The Office of Standard Weights and Measures shall hereafter be known as the National Bureau of Standards." Its scope was broadened consistently with the modern conception of standards and of the need for research and testing in applying them. Samuel Wesley Stratton, federal inspector of weights and measures in Washington, became its first director. During his administration of twenty-two years, the Bureau became a great institution famous throughout the world and notable for achievements in science and technology.

A beautiful site of 56 acres in the suburbs of Washington about three and a



NORTHWEST LABORATORY

half miles northwest of the White House is now occupied by its nine major and twelve minor buildings--a veritable city of science set on a hill. Originally suburban, it is now the center of a populous urban apartment district and the Bureau has moved certain types of work into neighboring states, notably an aviation engine testing station at Arlington, Virginia, and the radio research stations at Beltsville (17 acres) and Meadows (200 acres), Maryland. Other field stations provide for radio aids to aviation at College Park, Maryland; electric lamp inspection in the New York and Boston district; utilization of farm wastes at Ames, Iowa, and at Auburn and Tuscaloosa, Alabama; testing cement and concrete at Northampton, Pennsylvania, and Denver, Colorado; and testing cement, concrete and miscellaneous materials at San Francisco, California; and ceramics research at Columbus, Ohio. The latest of the Washington group is the National Hydraulic Laboratory, just completed and now being equipped, with a capacity to pump a volume of water per second equal to the water requirements of Washington, and in which fundamental prob-

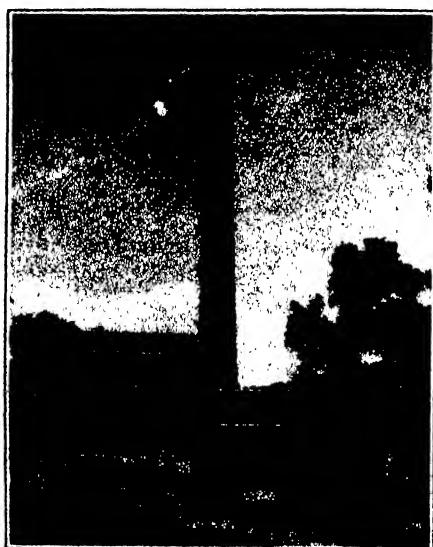


PLUMBING RESEARCH TOWER

lems of hydraulic power, flood control and irrigation will be solved experimentally. The Bureau group is well designed for its purpose and presents an impressive appearance—a resort of growing interest to tourists, a favorite target for airplane cameras, and a mecca for scientific and industrial experts meeting in Washington.

Under the research associate plan, evolved to perfect and extend the Bureau's cooperation with industry, an industrial group may maintain qualified workers at the Bureau of Standards for research under Bureau supervision on problems of mutual interest. The results are not patented but are for the free use of all industry. As many as a hundred associates from 45 organizations have been at work at the Bureau. The plan permits wise choice of crucial problems for joint attack by the Bureau and the industry, permits fuller use of the Bureau's unique equipment and staff, and assures more prompt application of research results by the industry.

Standards are classified by the Bureau in five groups: Measurement, Constants, Quality, Performance and Practice. The first two are the foundations. The functional diagram shows these classes of



POWER HOUSE

standards, defines them, illustrates them and indicates the purpose and service of each. Their scope broadly covers the measured controls and results of experiment and design—in brief, the quantitative aspects of science and industry. All five functional classes of standards may be involved in each of the scientific and technical specialties represented by the 70 sections of the Bureau's work. The length section has, for example, a basic standard of measurement (length), the meter; a basic constant (temperature), the ice point (0° C.) at which the standard is correct; a quality standard of finish and composition which assures the quality; a standard of performance for each length-measuring device tested; and a standard of practice to be followed by inspectors of trade length-measuring devices.

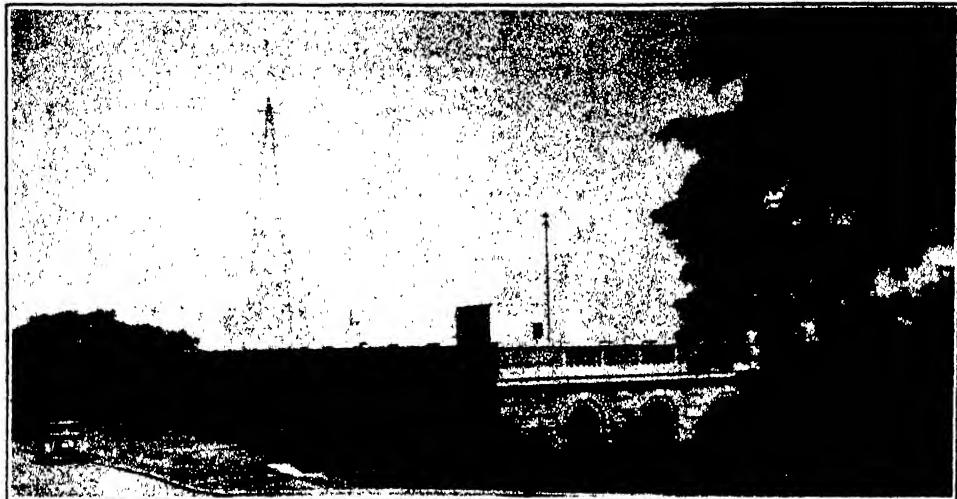
In theory every product of industry may have a similar group of pertinent standards. A gage block, for example, must have true size (standard measurement), a working temperature (20° C.) at which it is true size, a quality standard for the steel, its annealing and finishing, and a practice standard as to method of use for best results.

Let us consider further these five classes of standards: Measurement, Constants, Quality, Performance and Practice. In measuring light we meet the first group. Carbon filament lamps first used by the Bureau to maintain the unit of light, the candle, are standards. A new international standard of light, now proposed by the Bureau and built and operated with success, is an enclosure radiating at the freezing point of platinum (1773° C.). The radiated light is of definite quality and quantity and the unit candle-power can readily be derived from it with due accuracy. Standards of measurement are not fixed. They may be in any stage of development. The standard kilogram may be in almost a final form, but the standard of length now under investigation may eventually

be defined as a certain number of wavelengths of light rather than by a metal bar. "The solution of problems which arise in connection with standards" is a legal function of the Bureau which gives research a scope broad as measurement itself.

The numerical constants of nature are the second class of standards—boiling-points, atomic weights and a thousand similar magnitudes, established as a function of the Bureau by Congress. Under this authority the Bureau determined the atomic weights of hydrogen and oxygen (two fundamentals in chemistry), the constant of gravitation, the velocity of electromagnetic radiation (electrically determined as the ratio of the electromagnetic to the electrostatic unit). The speed of radio and light are credibly believed to be equal so that this constant is of both practical and theoretical interest. The Bureau's determination of the density of pure alcohol closely confirmed the classic determination by Mendeleef fifty years before and may remain standard for fifty years to come. The constants of refrigeration materials measured with high accuracy laid the basis for the era of refrigeration and controlled air conditions indoors. More recently the constants of steam and water were determined to give a similar basis for the new era of high pressure steam power.

Standards of quality are the third class of standards. They are specifications in measured terms which assure intended service with planned effectiveness. Reduction to measurement enables the factory to produce, the dealer to sell, the user to buy on an accurate standard basis of measured size, service, and efficiency. To-day these are indispensable to the interlocking factors characteristic of well-ordered industry. They become the maker's obligation, the dealer's promise and the buyer's understanding. The measured need and the measured product must match each



RADIO RESEARCH LABORATORY

other. The specification or the standard of size or quality is the modern means of assuring such matched measures. The Bureau's work in this field is notable. It promotes voluntary action by industry adopting specifications for products, and it publishes those approved as "Commercial Standards." At this writing 41 projects have been completed, and 33 are actively pending. Approval means that two thirds of the industry have given written approval. Some have as high as 90 per cent. approval, and a recent standard for woolen blankets has 100 per cent. approval. Besides this line of attack, some twenty-seven Bureau experts are chairmen of technical committees which have formulated 774 federal specifications for adoption by the Federal Specifications Board. The Bureau's new National Directory of Commodity Specifications refers to some 25,000 nationally recognized specifications of all kinds, enabling purchasing agencies, public and private, to avail themselves of these up-to-date sources of technical data required in intelligent buying.

Standards of performance specify the factors involved in the effective operation or action of machines and devices

in terms susceptible of measurement. The Bureau has by joint research and action aided in formulating such standards of performance as those for fabric measuring devices, gasoline pumps and other liquid delivery pumps, and track scales. For example, by setting limits to permissible errors and tolerances, we, in effect, set up a standard of accuracy. The manual for inspectors sets forth specific examples of such standards and the schedule of tolerances aids inspectors and helps to assure reasonable compliance with reasonable standards of performance. A working standard of performance may be illustrated by the test runs of aviation engines made at the Bureau for airworthiness certification by the Aeronautics Branch of the Department of Commerce.

Standards of practice, specifically codes of service and safety, are drafted by or under the auspices of the Bureau. Examples are the handbooks of weights and measures testing practice, codes of safety for the logging industry, for aeronautics, electric service, eye-hazardous industries, and others. The Bureau contributes to the fundamental science in such cases as illustrated by its research on the physics of plumbing systems

which involved experiments in a unique tower laboratory simulating conditions in a modern office building. The data were embodied in the code of minimum requirements for plumbing compiled by the Department of Commerce Building Code Committee and published by the Bureau of Standards.

Closely related to constants is the determination of the properties of materials, another function given to the Bureau by Congress (1901). Unusual facilities are available--experimental manufacturing plants in which materials can be made or modified under measured control with every facility for observation and record; induction furnaces for melting metals, a rolling mill, a plant for producing the lowest attainable temperatures, testing machines with capacities up to 10,000,000 pounds, and similar facilities in great variety. Its textile research staff has a modern laundry, devices developed at the Bureau to measure the wear of clothing, carpet or other fabric; ultra-violet light sources to measure the fastness of dyes; a complete mill to spin or weave any cotton yarn or fabric; a weather-controlled laboratory to keep the humidity and temperature constant and standard.

Special devices for the leather work include an experimental tannery, a sole-leather walking wear-machine, and means for measuring the resistance and strength of various tanngages. A paper mill and laboratory are equipped to produce any paper of any fiber under measured control and thus permit improvements in the properties of paper. Long life, for example, is a valuable characteristic for paper used as a vehicle for records of history, literature, science and industry. The Bureau found by systematic variation and trial that the sulfur dioxide in the air was the greatest enemy of permanence, almost regardless of the fiber composition. From 15 to 190 tons of sulfuric acid are deposited every year on each square mile of our

large cities. This causes a deterioration of cellulose by acid action. Control of the acidity in making the paper within a standard acid content has been found effective in assuring long life to the paper, provided it is properly stored and protected from acid atmosphere or direct sunlight.

A rubber mill, compounding room, vulcanizing ovens and a climate-controlled laboratory permit fundamental experiments in measuring and modifying the properties of rubber. Dynamometer tests here revealed power loss in tires through poor design, much of it preventable. The Bureau has by distillation obtained a transparent form of rubber, and under unusual conditions has crystallized it from ether solution at 40 to 65 degrees below zero centigrade. Other experimental mills for producing industrial products include the cement mill, optical glass furnaces, clay products mill and kiln, foundry, draw bench and others—an ensemble forming an industrial plant not operated for the market but in the interest of the maker and user of the respective materials, applying science to qualify production.

The Bureau of Standards, perhaps the first in which pure and applied science united on equal terms, stood alone in this country at the beginning of this century. To-day 1,620 research laboratories are listed. Many were inspired and aided by the Bureau. On the frontiers of knowledge these laboratories yield numerical data, new materials, new devices, new processes, thus creating industry for to-morrow.

Research results at the Bureau have been many, valuable and interesting beyond even sanguine anticipations—technique for producing and dimensioning high precision gage blocks, strengthening paper, producing semi-commercially a sugar new to industry, development of the radio direction finder, radio-beacon and blind landing system, use of light



EXPERIMENTAL PAPER MILL

IN WHICH ALL CONDITIONS MAY BE HELD CONSTANT OR SEPARATELY VARIED AT WILL.

waves to graduate standards of length, these and hundreds of other results have been reported in Bureau publications, some 2,000 of which have been issued. A descriptive catalog contains an abstract of each and a consolidated subject index of all published work of the Bureau. The value of accurate numerical data has made the Bureau a key institution in many technical fields. Its successes will be recounted in a series of articles which will follow this introductory statement.

Testing may be called "standards at work." The Bureau makes thousands of tests, but does not compete with private laboratories. In fact, the Bureau prefers that private agencies make all tests for which they are fitted and for this purpose has published a list of commercial and academic laboratories to aid those in need of testing services. It also cooperates in organizing such laboratories. An example in the field of cement is proving very successful. The

Cement Reference Laboratory maintained at the Bureau of Standards jointly by the American Society for Testing Materials and the Bureau of Standards inspects equipment and methods of any private laboratory free on request. This type of service adds repute to competent private laboratories and tends to raise the standard of inspectional and testing work and thus add assurance of the quality of cement delivered on specification.

Tests in great numbers are made for almost every branch of the government service to supply its needs for equipment and general supplies. Test schedules are so voluminous as to suggest a large supply catalogue. Devices as simple as a volumetric flask or complex as an aviation motor are tested to disclose flaws or excellencies. The measured response to service conditions aids the designer to conserve and make further progress, and the Bureau's inspection at the factories and tests in the

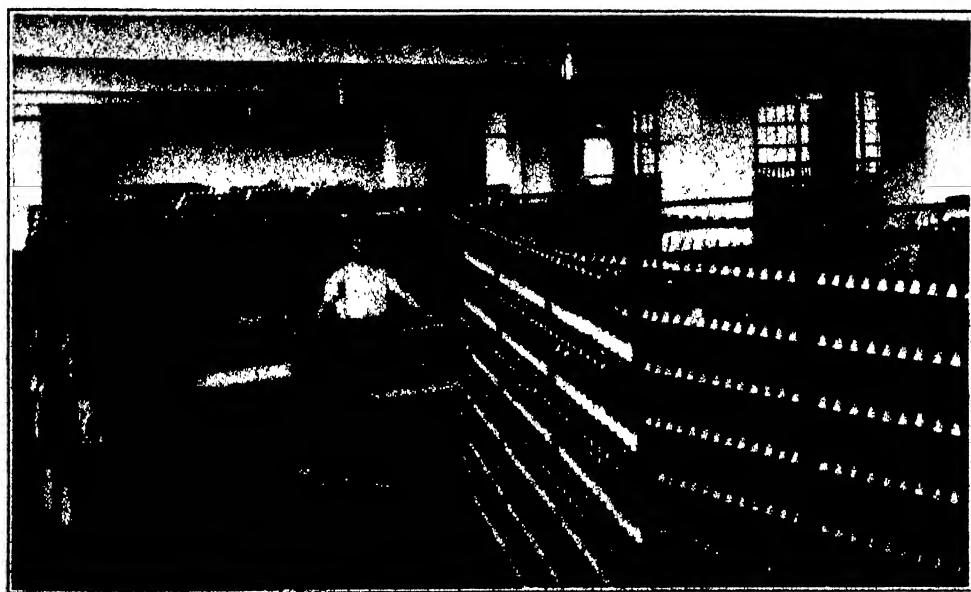
laboratory safeguard mill production and assure delivered quality. Factory inspection is made for cement and electric lamps. Tests are made to determine fitness for use or to settle disputes, the latter umpire tests being undertaken only if both parties agree to abide by the result. A useful type is the developmental test which aids the producer to measure the performance of new or improved materials, devices, and instruments. This, in fact, is one of the great benefits of the work to the ultimate consumer since it enables the Bureau to encourage increased serviceability by pointing out where improvement is needed. Some have thought the Bureau should commend specific brands, but those qualified to know believe that specific advice would be of prohibitive cost to secure and might be nullified overnight by changes in production methods or design.

The public as the ultimate consumer is directly aided by the Bureau's certification and labeling plans under which manufacturers agree to certify that their products meet the specifications of the

Federal Government. Lists of firms willing so to certify are furnished to federal, state, county and municipal officials making purchases from tax money, and to others only upon specific request from the individual.

Bureau results are varied and have appropriate outlets for each type. Its staff is widely represented on technical committees of national societies and carries the latest findings into actions by these societies and this knowledge thus enters practice. Visitors in growing numbers come to the Bureau to confer with its experts on problems of industry and carry away with them what the Bureau has to offer. Letters in large number are answered, giving information sought. Letter circulars, several hundred in number, cover topics of unusual public interest, serving a function midway between an especially typed letter and a printed publication. Finally, for the world and posterity, printed publications tell the story of the Bureau's varied activities.

The annual report gives by funds a brief yearly summary of achievements.



EXPERIMENTAL SPINNING MILL

The *Journal of Research* publishes research results, the *Technical News Bulletin* covers concisely all significant activities of the Bureau, the *Commercial Standards Monthly* prints special articles and current news of standardization, while the "Standards Yearbook" sums up world progress in standards and standardization as an annual work of reference and historical record of this world wide movement. Circulars of the Bureau contain announcements, compiled data and general information. Simplified Practice Recommendations promulgate the simplified schedules of reduced number of sizes or varieties as approved by a substantial majority of the industry. Commercial Standards in like manner promulgate standards of dimension or quality for materials and devices like-

wise approved by industry. The Miscellaneous series comprises annual reports, conference proceedings, charts, tables. The Handbook series comprises codes or standards of practice in a size convenient for the pocket of the technician in the field.

Later articles in this series will tell specifically how the Bureau of Standards touches American life at vital points, affecting equity in trade, efficiency in industry, accuracy in science, effectiveness in process and procedure. It is a matter of good business and wise statesmanship that it should continue to grow commensurately with the advances in science and technology. In fact, the Bureau of Standards has an important share, in fundamental ways, in promoting such advances.

SCIENTIFIC BY-PRODUCTS OF THE U. S. COAST AND GEODETIC SURVEY

By Captain R. S. PATTON

DIRECTOR, U. S. COAST AND GEODETIC SURVEY

INTEREST in scientific work and scientific discoveries is constantly spreading in step with their practical applications. Because of the present popular appreciation of the values of science, workers in border line fields are impelled to include their work in the category of science, thus greatly widening its range. A further explanation of the broadened scope of science is that the scientific method has become almost universal for attacking the many diverse and difficult problems encountered in our modern life, and many studies and investigations are now classed as scientific which were not so considered a few decades ago.

The Coast and Geodetic Survey is not primarily a scientific bureau but rather an institution of applied science. It does, however, carry on work of considerable scientific value. When the Bureau was organized over a century ago, its task was the very practical one of surveying the coasts and harbors of our country, so that the commerce of the world might find safe passage. This was a mighty task. The need for results was urgent and great. Fortunately, the level-headed man selected for the first superintendent, Ferdinand Rudolph Hassler, could not be stampeded into haphazard decisions and plans. Much ahead of his time in his mental attitude, he approached the task from a scientific view-point and, instead of adopting methods but slightly better than were needed to satisfy the demands of the time, spent several months in studying the best surveying methods then known and in devising and superintending the construction of precision instruments.

As evidence of his wisdom in attack-

ing the problem in this scientific way, it need only be mentioned that the first Hassler surveys meet modern requirements. His work had the solid foundation of adequate accuracy to satisfy future needs. Had he planned to meet only the needs of his time, he would have effected but a negligible saving, and his work would have had to be done over at greater expense in after years.

The Coast Survey, as it was first called, therefore, had a scientific beginning, even though the task assigned was a very practical one, and the inspiration of its first leader gave to the Bureau a tradition of high scientific endeavor which has been faithfully maintained. Some of its present valuable scientific by-products may be attributed to this tradition.

The work of the Coast and Geodetic Survey is still of a practical nature. Although its activities have increased many fold, none of its measurements or investigations is for purely scientific purposes. Its magnetic measurements are made to promote the safety of the mariner and to make it possible to retrace old surveys; not primarily to furnish data for theoretical studies of the earth's magnetic field. The measurements of tidal fluctuations and tidal currents are made for the prediction of tidal phenomena as an essential aid to the navigator; Harris's classical theories of the tides, a great addition to the scientific knowledge of the earth, are by-products. Gravity measurements are required to disclose the exact shape of the earth in order that geodetic surveys, which cover such large areas that the earth's exact curvature must be known, may be made with the necessary refine-



F. R. HASSLER
THE FIRST SUPERINTENDENT OF THE U. S. COAST SURVEY.

ment. It is only incidental that the theory of isostasy was confirmed and reasonably established by means of geodetic data already at hand for the control surveys of the country.

These are typical examples. Many more could be cited to show how the practical work of the Coast and Geodetic Survey has resulted incidentally in yielding scientific data of great value.

In 1878, the designation of the Bureau was changed to Coast and Geodetic Survey. Its most important work still remained the survey of the coast, but its geodetic activities had become consider-

ably expanded. To coordinate the charts of the Atlantic and Pacific coasts, an arc of triangulation across the entire country was essential and the great arc along the 39th parallel, over 2,000 miles long, was carried out.

Before the positions of the stations along this arc could be accurately computed, it was necessary to determine the elevations of the stations at the ends of the various base lines in order that all lengths of the triangulation could be reduced to a common datum plane. Lines of levels were therefore run and the elevations above mean sea-level de-

termined for a large number of permanent points called bench marks.

Engineers and surveyors immediately recognized the value of these precise geographical positions and accurate elevations and wherever possible began to connect local with the more comprehensive national surveys, creating a demand for extensions of the control surveys into other parts of the country.

A similar expansion of the magnetic work of the Bureau took place at about the same time. The magnetic part of the Bureau's activities, begun in 1843, had for its purpose the furnishing of much needed information to navigators and surveyors about the behavior of the magnetic needle.

The magnetic needle, as is well known, is very erratic and does not in general point true north. Its deviation varies from place to place and from day to day. It even has an hourly variation and a speacial variation due to magnetic storms.

When land was cheap, property and boundary lines were almost universally laid out with a compass, with the corners sometimes not marked at all or often poorly marked. After property became more valuable, the surveyor retracing these lines had to determine the deviation of the needle at the particular time of the original survey. This information was ordinarily available only in case comprehensive magnetic surveys extending over a number of years had been made covering the area in question.

The safety of navigation depends to a very great extent upon the compass and the navigator's knowledge of its behavior. Like the surveyor, the navigator must know the variation of the needle from true north, but in addition he must also know to what extent his compass is affected by the iron in his ship. The latter is a difficult problem and its solution requires a knowledge of the dip

(inclination) and the intensity of the earth's magnetic field.

Altogether, to meet the needs of the navigator and the surveyor and now of the aviator, a great mass of data had to be collected. These data are useful not only for the particular purposes enumerated above but have great scientific value. In conjunction with similar data over the oceans, collected chiefly by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, they made possible extensive investigations of the earth's magnetic field, and of possible correlations of magnetic variations and storms on the earth with sunspot activity and other important studies. Although these intensive investigations are mostly carried on outside the Coast and Geodetic Survey, they depend in part for their accuracy and the wide range of problems they cover upon the data accumulated by this Bureau.

The seemingly diverse major activities of the Coast and Geodetic Survey are related, as an enumeration of them will show. Perhaps the first item in our enumeration should be geodetic astronomy, for before any accurate survey can be made, starting points must be established and true directions to other points determined by astronomical observations. Latitudes, longitudes and azimuths, determined astronomically, may therefore be compared to the foundation of a building. They serve as a beginning for all other surveys.

Next in our enumeration should come triangulation, because that is needed next. The geographic positions of a large number of points are required as a basis for hydrographic, topographic or other surveys. To make astronomical observations at every station would require too much time and expense. Even then, the results would not be satisfactory. Astronomical observations are affected by deflections of the verti-

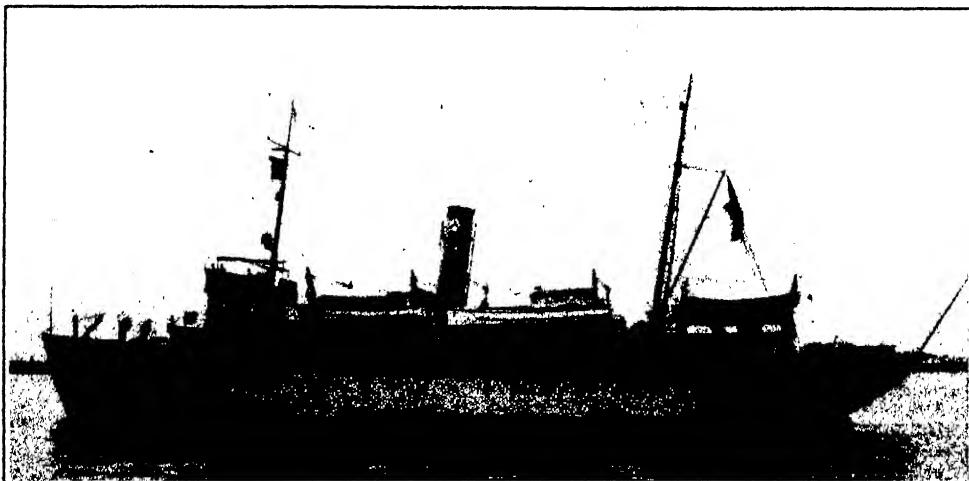


U. S. COAST AND GEODETIC SURVEY STEAMER EXPLORER AT PRINCE WILLIAM SOUND, ALASKA

eal, so the exact relative positions of points on the ground can best be obtained by triangulation. Base line measurements should be included with triangulation, since they furnish the starting and check lengths at intervals through an arc.

Hydrographic surveys should be mentioned next. Knowing the positions of triangulation stations on shore, the

hydrographic engineer determines the position of his sounding boat and soundings. As the depths read on the sounding line depend upon the tide, the variations of the height of the tide must be measured at points along the shore and a uniform datum plane established to which all soundings are referred. Tide and current observations are required, of course, further to insure safe



COAST AND GEODETIC SURVEY STEAMER SURVEYOR

navigation along the coast and in harbors. Hydrographic operations likewise include wire drag surveys, by means of which pinnacle rocks and other hidden dangers, missed by the sounding line, are discovered.

The magnetic work of the Coast and Geodetic Survey has already been mentioned and its purpose briefly described. The final item in our enumeration is the seismological work of the Bureau. This covers not only the recording of earthquake shocks at a number of field stations and the location of epicenters from data sent in by these and other widely scattered observatories, but includes also the periodic redetermination of

carefully collected, used for scientific purposes? Let us consider a few.

The Coast and Geodetic Survey publishes over 700 different charts of the waters under the jurisdiction of the United States. Over 277,000 of these charts were distributed during the last fiscal year. The data actually shown on each chart is only a small fraction of that used in its construction. To obtain the delineation of the bottom of a harbor or of the waters along a section of the coast, the hydrographic engineer must make a great number of soundings. Only a few of these can be placed on the chart in the space allowed without making it so confusing as to destroy



SURVEY PARTY LANDING THROUGH SURF

geographic positions and elevations to detect earth movements in seismic regions.

It may be asserted that all the activities enumerated above are carried on with scientific accuracy; an accuracy permitting the results to be used with confidence for scientific studies and investigations. There is no danger of the conclusions reached being in error because of uncertainties in the original data, beyond those due to unavoidable observational inaccuracies.

In what ways are all these data, so

its value. As the critical or characteristic depths are useful to the navigator, they are the only ones shown on the finished chart. A count of the field records used in compiling a typical single chart showed that information needed in its production appeared in 469 field sheets, sounding and tidal records and volumes of data.

When the data needed to produce one chart are multiplied by more than 700, the total is enormous. But we must go even beyond that. Certain sections of our coasts are sandy and the action of



RADIO ROOM ON SHIP GUIDE

SHOWING INSTRUMENTS AS SET UP IN RADIO ROOM. THE ORIGINAL EXPERIMENTAL WORK IN R. A. R. WAS DONE BY THE SHIP *Guide*.

winds and waves constantly builds new shoals and reefs, tears out old ones, and changes the location and characteristics of the shore line. New roads and streets are constructed along the shore, in the harbors new wharfs are built or changed along the water fronts, and new or deeper channels are dredged. New surveys must therefore be made from time to time to determine these changes, necessitating revised editions of charts. The number 700 therefore represents only a fraction of the total number of charts, if separate editions based on new surveys are included.

For what scientific purpose are all these data useful? The first that comes to mind is the problem of coast erosion. While this has a very practical side in

connection with the protection of waterfront property or the building up of new land, it has also a scientific side. How is erosion affected by the configuration of the bottom, the character of the material underlying adjacent water areas, the presence of outlying reefs, the prevailing direction of the wind, the oceanic and tidal currents, or the temperature or salinity of the water? A comparison of a series of revised editions of charts of a particular area shows exactly what changes have taken place in shore line, channels and reefs, and character of the bottom, and if the charts do not give sufficient detail, field sheets and other original survey data are available in the Bureau.

Much of the data needed for a scien-



FLOATING SIGNAL FOR OFFSHORE HYDROGRAPHIC SURVEYS

tific investigation of the problem, therefore, are furnished by the surveys of the Coast and Geodetic Survey. Although only a bare beginning has so far been made on coast erosion investigations, the problem will undoubtedly be studied intensively in the future.

Geologists for a long time have been interested in the continental shelves. What explanation can be given for these shelves? Are they rising or sinking, and are they affected by the weights of sediments deposited on them by rivers? A study of the charts covering these shelves show what are apparently the remains of old river valleys that are now submerged. Some investigators detect the results of glacial action on the continental shelf off New England. Tidal data show whether there is any tendency of at least the shoreward side of the shelf to rise or sink. Large changes in depth on other parts of the

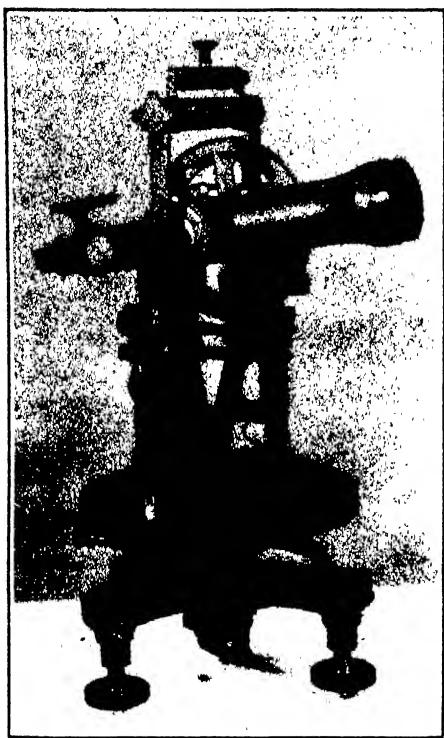
shelf are revealed by a comparison of soundings made at different dates, provided the character of the evidence is such that the changes found need not be attributed to other causes. Considerable scientific study has recently been given to continental shelf problems, based to a large extent on Coast and Geodetic Survey data.

During the past few years much study has been given to the question of the velocity of sound through sea water. An important reason for this study has been two new developments in hydrographic surveying methods, one an improved method for sounding in deep water, and the other a more accurate method for determining the position of a surveying ship at such a distance from shore that land is no longer visible. The accuracy of the results obtained by either method depends upon a precise knowledge of the velocity of sound through sea water under different conditions of temperature, salinity, etc.

The new method for sounding in deep water is called sonic sounding. A

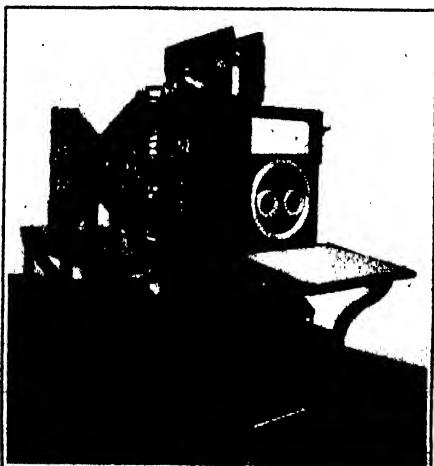


PLANE TABLE SURVEYING IN SOUTH-EASTERN ALASKA



PARKHURST THEODOLITE

THIS INSTRUMENT IS USED TO MEASURE THE ANGLES OF TRIANGULATION. SCIENTIFIC ACCURACY IS OBTAINED IN THE MEASUREMENTS MADE WITH THIS INSTRUMENT AND THE WORK CAN BE DONE VERY RAPIDLY.



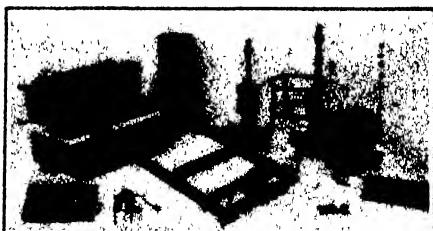
U. S. COAST AND GEODETIC SURVEY
TIDE PREDICTING MACHINE



ACCELEROGRAPH FOR USE IN REGISTRATION OF STRONG SEISMIC MOTION. THIS COMPLETE UNIT CONSISTS OF A THREE-COMPONENT WENNER ACCELEROMETER, PHOTOGRAPHIC RECORDER, TIME MARKING CLOCK AND A TWO COMPONENT STARTING ACCELEROMETER OF THE TYPE DEVELOPED AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

sharp sound emitted from the ship is reflected back as an echo from the ocean bottom. If the time required for the sound to travel to the bottom and back is accurately recorded, the depth of the water can be computed.

The method for fixing a survey ship's position when out of sight of land is called radio acoustic position finding. A bomb is exploded under water near the ship and the sound waves, traveling through the water, operate hydrophones at known points along the shore. The hydrophones, in turn, trip radio transmitters, each of which automatically sends a radio signal back to the ship. Since radio waves travel with the velocity of light, the time interval between the bomb explosion and the return radio signal is essentially the time required



MAGNETOGRAPH AND EQUIPMENT OF THE LA COUR TYPE AS USED AT THE COLLEGE-FAIRBANKS POLAR YEAR STATION, COLLEGE, ALASKA, FOR REGISTRATION OF THE VARIATIONS IN THE EARTH'S MAGNETIC DECLINATION, HORIZONTAL INTENSITY AND VERTICAL INTENSITY.

for the sound wave to travel from the ship to the shore station.

One phase of radio acoustic position finding requires scientific investigation beyond the study already given to it. The path followed by the sound wave in going from ship to shore is not yet definitely known, or a better statement of the problem would be that the path followed by that part of the sound wave which first reaches the hydrophone is not definitely known. The velocity of sound is different near the surface from what it is near the bottom, and the accuracy of the position determined by this method depends upon how nearly the actual sound path can be ascertained.

There are of course other important scientific investigations which are based on the hydrographic data of the Coast and Geodetic Survey. There are also a number of outstanding problems, the solutions of which are dependent upon other kinds of data collected by the Bureau. Let us consider a few of them.

Mention has already been made of the effect of deflections of the vertical on astronomical observations. Ever since Newton's time the laws governing the attractions of bodies of matter have been known to a high degree of approximation. With these laws and a sufficient knowledge of the topography of the earth it should be possible, theoretically, to compute for a given point on the earth just how the bob of a plumb line will be attracted by the earth's mass as a whole. If there is a mountain a certain distance from the station in a given direction, we know the attraction of the mountain will pull the plumb line slightly to one side. If the size and distribution of mass of this mountain are known, its effect on the plumb line can be computed.

A strange thing was noticed many years ago when attempts were made in India to compute the attractive effects of mountain masses. The apparent



BROWN GRAVITY APPARATUS

THIS IS A NEW TYPE OF PENDULUM APPARATUS RECENTLY DEVELOPED BY THE COAST AND GEODETIC SURVEY. RESULTS OBTAINED WITH IT IN WYOMING DURING THE FALL OF 1932 HAVE BEEN OF GREAT SCIENTIFIC INTEREST TO GEOLOGISTS WHO ARE STUDYING THAT REGION.



THE FATHOMETER, AN INSTRUMENT FOR ECHO SOUNDING



LATITUDE OBSERVATORY, GAITHERSBURG, MARYLAND,

ONE OF TWO OBSERVATORIES IN THE UNITED STATES OPERATED BY THE COAST AND GEODETIC SURVEY UNDER INTERNATIONAL AGREEMENT FOR THE SCIENTIFIC STUDY OF THE VARIATION OF LATITUDE. THE RESULTS ARE COMBINED WITH THOSE FROM SIMILAR OBSERVATORIES IN OTHER PARTS OF THE WORLD.

actual attraction of a mountain was found to be much less than the computed effect. The only explanation found for this lack of attraction was that there must be some form of compensating negative mass underlying the mountain. This theory, in two different forms, propounded about the middle of the nineteenth century by two famous English geodesists, Pratt and Airy, later became the basis for the well-known isostatic theory.

Early in the twentieth century, a quantitative test of the isostatic theory in the Pratt form was made by the Coast and Geodetic Survey. It was assumed that the crust of the earth above a uniform imaginary surface about seventy miles below sea-level is in floating equilibrium, that is, that a mountain is balanced by an equal negative mass directly below, and that an ocean is balanced by an equal positive mass below it. Computations showed the theoretical deflections of the vertical on this basis were remarkably close to the actual observed deflections. Several hundred astronomical stations were used in this investigation and the results were almost conclusive proof of the main essentials of the isostatic theory.

The practical result of this investigation was that the Survey was able to derive the shape of the earth so accurately that its mathematical spheroid was adopted as the standard international ellipsoid to be used as the basis for triangulation computations and adjustments.

Later the Survey applied the isostatic theory to the computation of the intensity of gravity, again strikingly demonstrating the general truth of the isostatic theory. Theoretical values of gravity computed on this basis came much closer to actual observed values than by any other method proposed for the computation of gravity. The first immediate practical result of this investigation was a check on the shape of the earth as derived from astronomical data. Another important result was the theory that some indication of the kind of material concealed in the upper part of the crust could be obtained by comparing values of gravity computed on the isostatic theory with actual observed values. If the computed value of gravity is too large, the station is probably above a mass of rock of density less than normal; if too small, it is probably on a mass of heavy rock. As

a result of this discovery the gravity method is now used in conjunction with other scientific methods in the search for oil and minerals.

The isostatic theory has been tested on both land and sea in many parts of the world, and has not only been definitely proved to be an accurate workable theory of the earth's crust, but it has also served as the basis for certain geological investigations, as, for example, the effect of glacial loading and unloading on the elevation of the underlying crust, the relation of synelines to heavy rock formations, and the effect of erosion and sedimentation on the equilibrium of the earth's crust. Accordingly, our knowledge of the interior of the earth has been increased very considerably by means of the isostatic method of attack.

I should again touch on one of the more recent activities of the Coast and Geodetic Survey, namely, its seismological work, formally assigned to the Bureau in 1926. Seismographs had already been in operation at its magnetic observatories for a number of years. It

had been suspected that the magnetic records at the observatories were affected at times by earthquake disturbances. It was therefore necessary to record earthquakes in order that the magnetic measurements might be freed of their effect. The seismograms thus obtained were also found very valuable for earthquake study and consequently were made available for the use of seismologists. Here again we see a very practical need underlying the collection of data which later proved to have scientific value.

The Coast and Geodetic Survey now obtains earthquake data not only from its own observatories but from a number of cooperating organizations in this country and abroad. It determines the positions of earthquake epicenters from these data and publishes results at regular intervals. It has installed new and better types of instruments at its observatories and the data collected are constantly becoming more comprehensive and valuable.

Why study an earthquake after the damage has been done? Perhaps the



AIR VIEW OF THE SAN JUAN MAGNETIC OBSERVATORY,
NEAR SAN JUAN, PORTO RICO, AT WHICH CONTINUOUS PHOTOGRAPHIC RECORDS OF THE EARTH'S
MAGNETIC ELEMENTS ARE MADE. THE COAST AND GEODETIC SURVEY OPERATES FIVE OF THESE
OBSERVATORIES WELL DISTRIBUTED OVER THE UNITED STATES AND POSSESSIONS.



LANDING ASTRONOMIC AND GRAVITY INSTRUMENTS AT NIHOA ISLAND OF THE HAWAIIAN GROUP

best general answer to this question is that we are rapidly increasing our technical knowledge of earthquakes and there can be no doubt that this knowledge eventually will be of great value in helping mankind to minimize the detrimental effects of such disturbances. Investigators are learning where earthquakes are most likely to occur, what kinds of waves are produced in the ground near the epicenter and how these waves travel, what buildings are most likely to resist shocks, and what changes occur in the positions and elevations of points on the ground before, during and after the shock.

An interesting scientific study of the interior of the earth is possible from seismic data. An earthquake shock is recorded at distant points because of earth waves emanating from the epicenter. These waves are of two different types and travel along several different paths near the surface of the earth and through the interior. A great deal of our present knowledge about the crust of the earth and the so-called central core has been obtained by a study

of earthquake records. Much has been learned about the speed of travel of the different waves along the various paths, and the relation of the speed to the elasticity and other properties of the rock through which the waves pass. This knowledge has been applied by geologists to the search for oil and other minerals by the simple expedient of making use of artificial earthquakes suitably located and produced by explosions.

In preparing this paper I have purposely avoided giving any technical details of the work carried on by the Coast and Geodetic Survey. My purpose has been to present a general picture of a broad field and to leave it to the reader to pick out the subject in which he is most interested and then obtain the details from a more technical treatise. I trust I have shown that the work of the Coast and Geodetic Survey, done primarily to meet practical, every-day needs, contributes in a very real sense to an increase of the scientific knowledge of the world, without which mankind can not expect to advance.

CAJAL'S SUGGESTIONS FOR THE SCIENTIFIC INVESTIGATOR

By Dr. WILLIAM A. HILTON

PROFESSOR OF ZOOLOGY, POMONA COLLEGE

S. RAMON Y CAJAL is especially well known to the histologist and neurologist for his most important contributions to our knowledge in the field of the nervous system and sense organs. Few men in science have received such complete recognition during their lives and none have more justly come by these honors. Besides his numerous technical monographs and books are a few others of a more literary character. He has kindly granted me the privilege of drawing freely from two of these in connection with an account of his life. They are his autobiography and "Rules and Counsels for Scientific Investigation." This last has so much of interest and value that I have translated from the Spanish some of its striking passages before a more comprehensive work is published.

On the whole Cajal is appreciative of the value of philosophy, but he says:

" . . . The history of civilization has unmistakably demonstrated the sterility of metaphysics in its repeated efforts to divine the laws of nature. It has been rightly said that the human intellect, turning its back to reality and concentrating in itself, is powerless to explain the most simple mechanisms of the world and life."

" . . . I think myself that the slight benefit derived from the reading of such works and in general of all works concerning the philosophical methods of investigation, results from the vagueness and generality of the rules that they contain; when they are not empty formulae, they come to be the formal expression of the mechanism of thought in the investigating function. This mechanism acts unconsciously in every mind regu-

larly organized and cultivated; and when by an act of meditation the philosopher formulates his psychological laws, neither the author nor the reader can by their use improve his respective capacities for the scientific investigation. The expositions of logical methods cause in me the same impression that would be produced by an orator that pretended to increase his eloquence through the study of centers of voice production and the mechanism and innervation of the larynx, as if knowledge of these anatomic-physiological devices could create an organization that we lack or perfect the one that we have."

"It is important to note that the most brilliant discoveries have been due not to the knowledge of written logic, but to that living logic that man possesses in his spirit, with which he elaborates ideas with the same perfect unconsciousness with which Jourdain spoke prose."

He declares that there are no logical receipts for making discoveries.

"The men of genius hardly bow to written rules; they prefer to make them. As Condorcet says: 'The mediocre can be educated, but genius educates itself.' "

However, Cajal suggests that if we abandon vague philosophical principles and abstract methods, we may find the "moral and instrumental technique indispensable to the inquisitive process; it will be easy to find some rules positively useful to the beginning investigator." It is to the *will* more than to the intelligence that his suggestions are directed. He has the belief that the first is as capable of education as the second and also that every great work, in art, in science, is the result of a great desire.

"Excessive devotion to genius has its

root in a double sentiment of justice and modesty which is hardly to be blamed, but if it takes too great possession of the beginning investigator it destroys all initiative and incapacitates him for original investigation. Defect for defect, arrogance is preferable to bashfulness. Boldness tries its strength and conquers or is conquered, but excessive modesty avoids the battle and condemns itself to shameful inaction. . . .

"Far from becoming discouraged before the great authorities of science, the novice in investigation ought to know that his destiny by a cruel, but inexorable law, is to grow a little at the cost of the reputation of the great authorities. . . .

"But it is not necessary to destroy; it is necessary to build. Scientific criticism justifies itself, delivering in place of an error a truth. Commonly the new doctrine will come out of the ruins of the abandoned and will find itself resting on the facts rightfully interpreted."

Recent graduates, so Cajal says, are often heard to express such sentiments as these:

"All the substance of each scientific theme has been exhausted. Of what use is it for me to add some small detail? How can I hope to reap where more diligent observers have already collected abundantly? . . .

"So speaks laziness, many times masquerading as modesty. That is the way some youths of merit think when they feel the first dismay produced by the consideration of a great enterprise. . . .

"In general it can be affirmed that problems are not exhausted, but men are exhausted in a problem. Fresh talent arriving without reputation to the analysis of a subject will always find a new aspect, something that was not noticed by those who definitely abandoned the subject. So fragmentary is our knowledge that even in the most studied topics there are unexpected findings. . . .

"In the struggle with nature, the

biologist and the astronomer must do away with the earth which he inhabits and concentrate his attention upon the severe region of the idea where sooner or later the light of truth will appear. The new fact established, the applications will come in their time."

Cajal believes that many who declare themselves lacking in ability for scientific research are those who take this attitude to explain their laziness. Those not fitted for this work would be: "those not capable of prolonged attention and lacking curiosity or admiration for the works of nature."

Patience, ability for details, constancy, may be acquired, "with the habit of work and the satisfaction of success." Many of medium qualities may do something for as he says:

"Science like the army needs generals and soldiers, some to conceive the plan, others to work out details. . . .

"A dominant characteristic in the eminent investigators is the high, proud independence of judgment. They do not fall surprised and confounded before the work of their predecessors and teachers but remain impatient and inquisitive. . . .

"Men of science are moved by the same impulses as others, but two dominating forces are clearly seen, 'the cult of truth and the passion for glory.' "

" . . . the sincerest and the most devoted scientist remains profoundly human; in his life for his fellow beings he exceeds the best, expanding his usefulness beyond present and local conditions. Thanks to these men of singular talent whose sight penetrates into the shadows of the future, and whose exquisite sensibility makes them regret the errors and the stagnation of routine, in scientific progress only the genius can have the privilege of opposing the current and modifying the moral medium. His mission is not the adaptation of his ideas to those of society but the

adaptation of society to his ideas, and if he is right (as he usually is) and proceeds with prudence and energy, without dismay, sooner or later humanity will follow him, applaud him and cover him with glory. Trusting in this pleasing tribute of veneration and justice, every investigator works with confidence because he knows that if individuals are capable of ungratefulness, communities very seldom are if they reach full consciousness of the reality and utility of an idea.

"It is a very common truth that in a variable degree the desire for approbation and applause moves all men and especially those endowed with a great heart and wondering mind, but each one searches for glory by a different road. One is a soldier with the arms so celebrated by Cervantes in his Quixote and another aspires to increase the political greatness of his country. Others through art are desirous of the easy applause of the multitudes that understand beauty much better than truth. A few only in every country and in the more civilized, follow the path of scientific investigation, the only way that can bring us to a rational and positive explanation of man and of nature which surrounds him. I think that this aspiration is one of the most dignified and laudable that man can follow, because perhaps more than any other it is impregnated with the perfume of love and universal charity. . . .

"It is considered important that the beginner know thoroughly the literature of his field, not alone must he depend upon printed information but he must constantly return to nature herself. He must know in a general way all the other sciences which directly or indirectly have connection with the selected field. . . .

"The inquisitive mind is like a weapon of combat. If it is sharpened on one side only we shall have a cutting sword, if on two sides it will still be able to cut but less efficiently, but if we sharpen it on

three or four edges, we diminish its effectiveness until it is converted into an inoffensive quadrilateral. A bayonet could, if necessary, cut, but not without considerable motor energy, while a knife sharpened on one edge is terrible in the hands of a baby. . . .

"A knowledge of the German language is indispensable for one who would be up to date in a knowledge of current science. After the German, English and French follow in importance.

"We learn much from books, but we learn more in the contemplation of nature, cause and occasion of all books."

"All descriptions, no matter how objective and ingenious, they might seem, constitute the author's personal interpretation. It is known that a man mixes his personality with everything and when he thinks he is photographing the external world he frequently contemplates and pictures himself."

"On the other hand observation furnishes, besides the empirical data with which we have to form judgments, certain emotional factors as: surprise, enthusiasm, agreeable sentiments, that are propelling forces of the constructive imagination. The emotion lights the cerebral machine which acquires by it necessary heat, the forge where fortunate intuitions and hypotheses will be wrought. . . .

"After choosing the theme of study and being informed in detail if possible of the actual state of the point to be elucidated, the investigator will pass on to apply as many analytical methods as have been proposed, with the object of confirming the facts described and reproduced in the most recent monographs."

"Among the procedures of study will be chosen by preference the most recent ones, and above all, the most difficult, because they are the least exhausted. The time spent in fruitless essays matters little, for if a method offers great differentiating powers the results obtained

will have great importance and will abundantly repay our efforts. . . .

"The new idea found is frequently the fruit of patient and tenacious observation, the consequences of having applied to the theme more time, more constancy and the best methods of one's predecessors. . . .

"The first fact conquered, our task will be as easy as brilliant, for it will reduce itself to progressively determining the consequences that the new acquisition has in different spheres of science. It has been said that although the first discovery is hard, the others are usually corollaries of the first. . . .

"The explorer of nature, we repeat it several times, must consider investigation as an incomparable sport, in which everything from the technical procedure to the doctrinal elaboration constitutes an eternal fountain of grateful satisfactions. . . ."

Diseases of the Will: This is one of the most interesting parts of the book. I can not do better than quote parts of the first two paragraphs of this chapter.

"We have all seen teachers superiorly endowed, overflowing with activity and initiative, possessors of sufficient means for investigation and yet who do not realize the value of personal work and never write. Their disciples and admirers await with anxiety the 'Great Work' which will justify the high concept of the teacher that they have formed; but the important monograph is not produced and the teacher continues without writing a word."

"Let us not be deceived by optimism and good will. Despite the exceptional merit and zeal and the energy shown in certain teaching activities, such teachers have diseased wills." Cajal divides these into several groups:

Contemplators: He begins with the sleepy variety, frequent among anatomists, chemists, biologists and physicists. It is recognized by the following symptoms:

"Love for the contemplation of nature, but only in its aesthetic manifestations, the sublime spectacles, the beautiful forms, the splendid colors, and the elegant structures. If the dilettante is a botanist, he will always remain anchored to an admiration of *Algae*, especially the diatoms, whose beautiful shells will captivate his admiration. In his fetishist cult he will spend his hours examining and photographing in a thousand ways, these interesting organisms, comparing them with Greek letters, shields, and other ornamental objects, but without adding to the copious catalogue of the known species a new variety, or contributing in the least to the knowledge of the structure, evolution and functions of the mentioned organisms."

Bibliophiles and the polyglots: "As the microscopist takes pleasure with the diatoms, the zoologist with shells, insects and birds of showy livery, the bibliophile will enjoy himself by reading very new books or monographs, or such transcendental writing from which he cares to receive only that which will astonish his friends with his vast knowledge."

"The symptoms of this ill are: encyclopedic tendencies, acquisition of many languages, some of them totally useless; exclusive subscription to little-known reviews; monopolization of as many new books as appear in the windows of book stores; assiduous reading of what is important to know, but especially that of interest to few, invincible laziness for writing and aversion for the seminar and the laboratory."

"As is natural our eruditus lives in and for his library, which is copious and monumental. He receives there those of his kind, to whom he engages in pleasant conversation with disconnected questions such as "Have you read this book?" (Here it may be a Yaqui, German, Russian or Scandinavian name.) "Do you know the surprising theory of so and so?" And, without hearing an answer, the eruditus develops, with warm

eloquence, a doctrine which is usually extravagant and audacious. All his eagerness is to pass as a monster of talent and of culture without thinking that only living effort can save the scientist from forgetfulness and injustice."

"There is not, fortunately, need of insisting much on this point to rectify mistaken social judgments. No one ignores the fact that the one who knows and does is valuable compared to the one who knows and goes to sleep. We render tributes of veneration to the one who adds an original work to a library and we deny it to the one who carries a library in his head. To become a phonograph, it would hardly be worth while to have the brain complicated with study and reflection."

The Megalophiles: "This variety is characterized by miscarried noble and sympathetic attributes. They study much and also love personal work; they possess the cult of action and dominate the inquisitive methods; they overflow with sincere patriotism and desire to honor their name and their country with admirable conquests."

"But nevertheless a remarkable error sterilizes their efforts. Convinced evolutionists in theory they are really providentialists in practice. As though they had faith in the miraculous they wish to start with a great deed. Remembering perhaps that Herz, Mayer, Schwann, Roentgen, Curie, initiated their scientific life with a great discovery, they aspire to ascend after the first battle from soldiers to generals, and they spend their lives planning and drawing, constructing and rectifying always in feverish activity, always in full revision, incubating the great product, the astonishing and overwhelming work. The years go by, expectation grows tired, competitors murmur and friends force the imagination to give an honorable appearance to the silence of the great man. And in the meanwhile, on that theme so carefully explored and can-

vassed, there comes an important monograph from a foreign country, which snatches from our ambitious investigator the flattery of priority and forces him to a change of direction."

Organophiles: "These are known by a kind of cult or fetish for the instruments of observation. Fascinated by the shining of the metal as the lark for the mirror, they take loving care of their idols, which they keep sacred, brilliant as mirrors and admirably preserved. Repose and content reign in the laboratory where there is not a stain seen or the least murmur heard."

"In the large pockets of the organophiles keys sound continually. It is impossible for the assistant or students in the absence of the professor, either to study the monographs or use the necessary apparatus. Microscopes, spectroscopes, balances, reagents, etc., are kept and sealed seven times! Nothing worse could happen, or be more greatly punished by the chief of the laboratory, than to have the assistant spoil the objective of Zeiss, the refractometer, the polarizer. That would be horrible! Besides, is he not the only one responsible for the scientific material, sacred chest of the University? And will he not some day have to render exact account to his superiors? Investigate! Confirm! He will do it when he has time, and when certain new monographs that are indispensable have arrived. Alas! If the Government would increase the budget for material, perhaps he would be able to spare, in the interests of teaching, part of the sacred deposit. But in the meanwhile! ! ! "

Those out of line: "The profession of teaching is at times a mere step to that of politics or an advertisement for professional work. . . ."

The Theorizers: "These are the cultured and superiorly endowed whose will suffers from a kind of laziness more grave because it does not seem such to them, nor to others. Here are the principal symptoms: talent for exposition;

unrestful and creative imagination; separation from the laboratory and inevitable antipathy towards concrete science and detailed facts. They prefer to see things large and live in the clouds. They prefer the book to the monograph and the brilliant and audacious hypothesis to the classic but solid conception. In the presence of a difficult problem, they feel an irresistible temptation, not to ask of nature, but to form a theory. If they happen to perceive a weak and artificial analogy between two phenomena, or succeed in putting the new fact in the frame of a general conception, true or false, they feel satisfied and they continue to believe themselves superior reformers. The method is legitimate in principle, but they abuse it, falling into the innocence of considering things under a single aspect. To them the essential is the aesthetic side of the conception. It matters little if it melts in the air, as long as it is beautiful and ingenious, profound and symmetrical. In reality the theoretical individual is a lazy person disguised as diligent. . . .”

Social conditions favorable for scientific work: Much of the material under this heading applies to conditions in Spain but there are a few paragraphs I wish to quote.

“. . . He goes on to say that in spite of such discouraged phrases as: “I lack a laboratory; my profession is incompatible with the equipment indispensable for scientific work; family obligations rob one of time and money required by the work of investigation”—that ‘

“It would be easy to reduce to its true value such laments and insist upon this important truth: *for scientific work the means are almost nothing and the man is very nearly everything.*”

Difficulties of material means: This is the convenient excuse which many professors and not a few doctors, not burdened with teaching but able for scientific investigation, present as soon as they are asked about their work. . . .”

“The investigator and the family: The worries and expense required in the creation and support of a family, in contrast with the poor pay which the state gives the teaching function, constitutes, as is well known, another of the reasons put forward by many of our teachers for deserting the laboratory and devoting their activities to more lucrative enterprises. ‘Science and the family are incompatible’ they affirm. ‘Since the physical basis of the professor is so small, how can he invite some one else to join him to share it? The scientist must choose between his spiritual family and his real family; between his ideals and his sons.’ It is correct to recognize it; in such exaggerations there is some truth. The care of the home, like the moral and economic struggle, takes from the work of investigation. The ideal university would be a monastery, whose monks, devoted for life to the study of nature, would have slight distraction from their regular duties.

“But we are too imperfect to consecrate ourselves with equal fervor to noble causes. The desire of heaven takes our interest from earth. It is well known that the psychologists, absorbed in the contemplation of the spirit, deprecate the brain. Those who occupy themselves about the devil laugh at the microbe. And the aspiration to eternal glory separates us from human glory. Glory! Vain illusion, no doubt, but capable of removing mountains and of giving ardent impulse to humanity towards the true and good. Like patriotism, the passion for glory must be suggested and never analysed.

“But the monastic life would result for the majority of scientists in intolerable sacrifice. . . . If woman is an ill, let us admit it, she is a necessary ill. Very few are the austere for whom the beautiful half of the human race represents something like a showy sample of an ornithological collection! Besides, it would be a poor procedure for the win-

ning of followers to offer them abstinence and martyrdom. Let any who can deny himself do it, but let us not impose that on any one."

"*Selection of a companion:* We touch here a very delicate point. What qualities should adorn the one chosen by the man of science? Many citizens suffer from their wives, but they suffer alone; but from the wife of the scientist sometimes society suffers and even the whole of humanity! How many important works have been interrupted by the egotism of young wives! How many vocations have been frustrated by feminine vanity or caprice! How many famous professors surrender to the weight of the matrimonial yoke, converting themselves into common gold finders, degrading themselves and sterilizing their work with the insatiable monopolizing of dignities and privileges."

"Even the most human and noble impulses of the wife, when they reach excessive conditions, constitute formidable enemies of scientific work. As is well known, there exists in the wife the spirit of the family, the saving tendency of the physical conservation of the race. It is wholly egotism since it represents the supreme interest of the species! Not without reason and depth has Renan said: 'What woman wants God wants.' She concentrates her love and abnegation in the family; less exclusive, the man knows how to distribute his efforts between the family and society."

"The woman loves tradition, adores privilege, feels justice little and is usually indifferent to all works of reform and progress; whereas the man truly deserves the title of homosocialist. He abominates routine and privilege, venerates justice, and places in many cases the cause of humanity before the cause of the family. That is why the mother wants to live only in the memory of her sons, while the father desires besides to survive in the pages of history. . . ."

"Arriving at this point, the reader

will wish perhaps, that we abandon the field of generalization and define the type of woman more adequate to the man of science. It is not a matter of indifference that the wife be for the man of study a gas that elevates him to the sky or a ballast that obliges him in the best of his life to land in the marsh."

"The intellectual wife, that is, the young woman adorned with a scientific or literary career, who, carried by irresistible vocation for study, has been able to acquire general instruction together with enough that is solid and varied; constitutes a very rare kind in Spain. One must, then, renounce such grateful company. It is sensible, no doubt because the few examples of woman doctors (except two exceptions) whom we have known in laboratories and clubs, seem, with their lack of charm, to console us for their being inaccessible."

"There abounds, on the contrary, in foreign nations, this feminine category, in which the scientific wife stands out with singular prestige, collaborator in the scientific enterprises of the husband, and exempt (as much as possible) from the frivolities and fantasies of the feminine temperament. Such a woman, intelligent and well balanced, with overflowing optimism and fortitude, constitutes the ideal companion of the scientist.

"Will he direct himself to the opulent woman? It seems to us a very dangerous choice. Habituated to an easy life of luxury, of display, it would be a miracle if she did not contaminate her husband with her tastes; repeating the case of the illustrious English physicist Davy, who on having been married to a rich woman, stopped almost totally his brilliant career of investigator and consumed the best part of his life in feasts and receptions of the great world."

"It would be great fortune to meet with a rich and illustrious heiress who, abandoning the caprices and vanities of the sex, would consecrate her gold to the

service of science. Admirable women of this kind abound in other countries."

"Shall the scientist prefer the artistic wife or the writer? With honorable exceptions, such females constitute perturbation or eternal occasion of disgust for the cultivator of science. It is discouraging to recognize that as soon as she enjoys a virile talent and culture, the woman usually loses the charm of her modesty, acquires airs of dominance, and lives in perpetual exhibition of abilities and excellences. The woman is almost always a little theatrical but the writer and the artist is always in the scenery. And then they have such high and complicated tastes! Anyway, the opulent wife usually pays for what she wants. Little friend of books or reviews, she is interested only in jewelry and stores of fashion; but the literary woman sees with equal desire the windows of jewels and hats and the show cases of the book stores."

There is left then for our beginning scientist as a probable and suitable companion of glories and fatigues none but the industrious girl who is economical and endowed with mental and physical health, adorned with optimism and a good heart and with enough education to understand and encourage the husband and with the necessary passion to believe in him and to dream of the hour of triumph, that she considers sure. And he, instead of scolding and rebuffs, will find in the home a grateful atmosphere propitious for the germination and growth of ideas. . . ."

MARCH OF THE SCIENTIFIC INVESTIGATION

Observation: "One ought to clear the mind from the prejudices and images of others to make firm the purpose of seeing and judging by ourselves, as though the object was created expressly for the comfort and delight of our intellect. It is necessary finally, to reproduce as much as possible the state of

mind—a mixture of surprise, emotion and vivid curiosity—through which the fortunate scientist went who discovered the fact considered by us, or who first attempted the problem."

"And this is closely associated with another rule praised constantly by the teachers of scientific investigation. It is not enough to examine, we must contemplate, impregnate ourselves with emotion and sympathy for the things observed, make them ours, both with the heart and by the intelligence. Only so will they deliver to us their secret. Like the lover who discovers daily in his beloved new perfections, the student who contemplates an object with delight ends by finding interesting details which have escaped others."

"We must work under the best possible conditions, taking advantage for the purpose of the more perfect analytical instruments and of the methods of study that deserve confidence. . . ."

Experimentation: "In many sciences experimentation surpasses in importance observation itself. It would be impossible to make discoveries in physics or in physiology, without imagining an original experiment, without subjecting the phenomenon studied to conditions more or less new. Morphology itself (histology, anatomy, embryology) for whose study mere observation seems to be enough, acquires every day a more experimental character. And to such a change of direction valuable conquests are due which never would have been achieved through the repeated method of the anatomical analysis of the static forms."

The directing hypothesis: "The facts observed, next it is important to fix their signification, that is, the relation that binds the new truth to the group of the postulates of science. In the presence of unusual phenomena the first move of the spirit is to imagine a hypothesis that will account for it and that places it under one of the known

laws. Experience will afterwards definitely pass upon the truth of the conception."

For the creation of the hypothesis he considers the following rules: *first*, that the hypothesis be required, *second*, that it be also contrastable or comparable, *third*, that it be easily imaginable, that is, translatable into physico-chemical language; *fourth*, that in escaping from occult properties and from metaphysical essences, it should tend toward solving the question of quality in problems of quantity; *fifth*, that it suggest investigations and controversies that bring us nearer to the good road, promoting new and more happy conceptions. Even though erroneous, the hypotheses can serve efficiently for progress if it be based on mere observations, and mark an original direction towards scientific thought. . . .

"It is difficult to dictate rules for imagining a hypothesis. The one who does not possess a certain intuition for causal linking or a guessing instinct to see the idea in the fact and the law in the phenomenon, will give a reasonable explanation very few times whatever his observing talent may be. . . ."

"Proof: The hypothesis, being imagined, it is necessary to submit it to the sanction of experience. For this we shall choose experiments or accurate observations, complete and conclusive. . . ."

"If the hypothesis does not conform to the facts, it must be rejected without pity, and another explanation imagined, which is free from reproach. Let us impose upon ourselves severe auto-criticism, based on self suspicion. During the process of proof, we should use the same diligence in searching out the facts contrary to our hypothesis as those that can favor it. Let us avoid feeling an excessive love for our own ideas. They should find in us not a lawyer but a judge. . . ."

"When the work of confirmation throws but a feeble light, let us imagine

new experiments and let us place ourselves in the best condition to evaluate the reaching of the hypotheses. In anatomy and physiology, for example, the impossibility of elucidating the structure or the function of a complex organ, occurs frequently. This results from the fact that we attack the problem from its more difficult side, pretending to solve it in man, or in the superior vertebrates. But if we go to embryos, or inferior animals, nature will show herself more ingenuous and less elusive, offering us almost the schematic plan of the structure and dynamism for which we looked and by which frequently our hypotheses will receive unexpected and definite confirmation. . . ."

Justification of the scientific communication: "Mr. Billings, wise librarian of Washington, oppressed by the task of classifying thousands of pamphlets in which almost the same facts or truths long known were brought forth in different styles, suggested to scientific writers the following rules: first, have something new to say; second, say it; third, stop as soon as it has been said; fourth, give to the publication appropriate title."

"Here is a suggestion which we do not believe useless in Spain, classical country of the hyperbole and the showy figure. In effect, the first thing that is necessary in treating of scientific subjects, when we are not trying to teach, is to have some observation or useful idea to communicate to others. Nothing is more ridiculous than the pretense of writing without being able to bring to the question a positive fact, with no other excuse than to show a feverish imagination, or to boast of pedantic erudition with data taken at second or third hand."

"Let us be sure, then, thanks to a careful bibliographic investigation, of the originality of the fact or idea that we desire to present, and let us keep from prematurely producing the fruit of our observation. When our thought

fluctuates between different conclusions and we do not have full assurance of having hit the target, it is a sign of having abandoned the laboratory too early."

Bibliography: "Before presenting our personal contribution to the theme of study, it is customary to sketch the history of the subject, either to mark the starting point or present a just tribute to the famous scientist who preceded us in opening the road of investigation. When at this point, either by love of conciseness, or by mere laziness, the beginning investigator tries to omit dates and quotations, let him consider that he might be paid in the same coin by others who intentionally ignore. . . ."

Justice and courtesy in the judgments: "In consigning the historical antecedents, we are frequently obliged to formulate judgments about the expositions of the work of others. It is unnecessary to give the warning that in such appreciations we ought to conduct ourselves not only with impartiality but by showing exquisite courtesy and agreeable and almost laudatory manners. Indulgent with the mistakes of the beginner, we should be respectful and modest before the lapses of the great scientific celebrities. Let us be always afraid that our observations represent superficiality or impatience or mirage of youthful enthusiasm before resolving ourselves to repudiate a fact or an interpretation commonly admitted; let us think maturely. And let us take into consideration when formulating our objections, that while among scientists we find noble and kind characters, there are also the irritable temperaments. . . ."

"When, unjustly attacked, we shall be forced to defend ourselves, let us do it bravely, using the sword, but with a blunt point, and adorned, as in the popular saying, with a bouquet of flowers."

"It is painful to recognize that in the majority of cases the contestants do not defend a doctrine but their own infalli-

bility. It is the instinct of spiritual conservation that reacts. . . ."

Error of observation or of recognizing of a fact: "In general scientists discuss interpretations, not facts, because they suppose that the investigator, no matter how modest he be, is not capable of going into the analytical theory without sufficient preparation. It is precisely for this that those lapses are considered very grave, showing in those who commit them singular intellectual candor of methodological experience. Nevertheless, let us keep from being abusive when pointing out mistakes; let us be kind and let us remember that in moments of distraction or carelessness even the most sagacious scientist can commit them. Far from criticising crudely, let us excuse him with benevolence, pointing out that it is a matter of very hard observations, when the mistakes result frequently and almost unavoidably. Let us not impute the error to ignorance, but rather to the imperfection of technique used to the prejudice of the school where the criticised work was inspired. . . ."

Theoretical error: "Let us suppose that in interpreting the facts incorrectly, the author formulated an arbitrary hypothesis bearing on the facts without basis in observation. The critical pill should be gilded with phrases of this kind: 'Certainly the explanation proposed is a little bit venturesome, but on the other hand it is notably ingenious, suggests very elevated considerations and shows in its author a philosophical spirit of great reach. It is a great pity that in forming his conception he had not taken into consideration those facts that contradicted it formally! In any case the hypothesis is seductive and deserving of respectful discussion and examination!'"

Exposition of the methods: "It is important to note either at the beginning or at the end of the monograph the methods of investigation followed. The

author should not imitate those scientists who give as a reason that they are going to perfect it later and so reserve for themselves temporarily the monopoly of the technique employed restoring the custom of the chemists and mathematicians of the centuries past who, inspired with the puerile vanity of astonishing the people with the power of their penetration, reserved for themselves the details of the procedures that had given them the truth. Fortunately this sort of thing is disappearing from the field of science."

Conclusions: "Presented in clear form, concise and methodical, the deductions and observations, product of our researches, we should close the work, condensing the positive results in a number of short propositions."

Need of drawings: "If our studies refer to morphology, either macro- or microscopic, it will be necessary to illustrate the descriptions with figures copied as exactly as possible from nature. No matter how precise and detailed the description might be of the observed object, it will always be of inferior clearness to a good drawing. Especially since the graphic representation of the things observed guarantees the exactitude of the observation itself, and constitutes a precedent of inestimable value for those many who confirm our conclusions. With reason almost the same credit is given to-day to the one who draws an object faithfully for the first time as to the one who makes it known only through a more or less incomplete description."

The style: "Finally, the style of our work will be genuinely didactic; sober, simple, without affectation and without having any other preoccupation than order and clearness. The emphasis, declamation or hyperbole, should never figure in the merely scientific writings, if we do not wish to lose the confidence of the scientists, who might end by taking us for dreamers or poets incapable of reasoning or studying a question

calmly. The scientific writer will aspire constantly to reflect the objective reality with the perfect serenity and honesty of a mirror, drawing with the word as the painter with the brush, and abandoning at last the pretension of an exquisite style and the fatuous boasting of philosophical depth. Let us not forget also the known saying of Boileau: 'That which is well conceived is clearly enunciated.'"

Publication: "When the investigator enjoys a world-wide reputation he will be able to publish his scientific contribution in any review of the specialty, foreign or national. The scientists interested in the subject will not stop at the obstacle of language, on the contrary they will try to study to know the thought of the other, or look for editors to translate and publish it. Nevertheless, even to the most famous scientists it will be necessary to communicate his discoveries to the *Beitrage* or *Centralblatt* more read in Germany. As far as the beginner without any credit in the scientific world is concerned, he will act very wisely at the start by asking hospitality in the great foreign reviews, and writing or making translations of his works into French, English or German. Those who, inspiring themselves in a narrow and base patriotism, refuse to write in any other than local reviews and read little or not at all in scientific countries, are condemning themselves to be ignored even in their own country."

"It is then imperative for the future of the beginning investigator that the judgment of foreign scientific authorities be obtained. He will reflect maturely before submitting to them the first work; let him be well assured through constant bibliographic exploration, and even better, by the consultation of some famous specialists, of the reality and originality of the communicated facts. And let him not forget that the right to make mistakes is tolerated only in those who have already made their reputations."

EARLIER DEPRESSIONS

By Dr. CAREY CRONEIS

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"LIFE allows you four depressions," is a sentence concocted by an astute advertising man. Nowadays it stares at us from many a newspaper and magazine page. It compels attention. Suggesting uses of adversity, it is somehow vaguely reassuring. We read on: "The average investor's life spans eight to ten depressions. Three or four are gone before he knows what to do with them. Yet, if he is wise and able he may profit substantially from the remaining ones. During every major decline thousands of investors have established the foundations for future independence by the purchase of sound securities whose values rose with the recovery of American business."

But to the average investor the advertisement is after all only vaguely reassuring. He remembers with distinct nostalgia one economist's pronouncement, on the eve of the Wall Street debacle, that "stock prices are on a permanently high plateau." He recalls further the good money he sent after the bad in that first incredible decline. He can't forget those popular predictions of complete recovery by 1931. He recognizes now, as merely a Delphic wisecrack, the radio counselor's statement that "the depression will be over two months before we know it." In short, it dawns on even the most gullible that, although the rebirth of prosperity will, indeed, be a "blessed event," there is no Walter Winchell to set the date. As a matter of fact, the less stout of heart are badly worried over such headlines as "Germany Refuses to Pay" and the many species of magazine articles which nevertheless all

belong to that ubiquitous genus, "When the Revolution Comes."

The trouble is that many of the investors who are hardest hit are really too young to remember any former depression; even the great majority of those who muddled through dull 1921 are already a little uncertain about what actually happened then; those who weathered the panic of 1907 have only a hazy recollection of its lessons, for their present discomfort is far more poignant than their ancient pains; the veterans who made fortunes out of the hard times of 1893 can marshal now only a few thin-ranked battalions. Leaderless, they have completely lost track of those earlier anxieties in a morass of present fears and a welter of apprehensions for the future. In short, even the most experienced lack perspective. In the quiet of their clubs they say to one another, "Yes, we've always come out of it before, and I suppose now may be the time to step into the market; but, confound it, John, things are different *this* depression. How do we know we'll ever come out of it? Look at Russia!"

Their forefathers for generations have had the same misgivings. Some of them wondered, with Lincoln, if the nation really could survive; others, with Washington, felt skeptical of the future of the colonies. Likewise, unknown Crô-Magnon leader, forgotten Basque chieftain, Sargon of Khorsabad, Hamilcar of Carthage, Nero of Rome, Caradoc of the Silures, Genghis of the Gobi, Lorenzo of Florence, Bonaparte of Corsica, Wilhelm of Prussia and Hoover of Palo Alto—all have realized fully the

story the past tells of the unending alternation of good and bad times. But they, even as you and I, have always felt that, regardless of the past, "Things are different *now*." Either "rich years will change only to become richer," or "hard times are only the harbingers of complete ruin," have run their thoughts, according to the particular circumstances under which they lived. In other words, whether ancient, medieval or modern, the historians, philosophers, courtesans, priests, soldiers, medicine-men, artists, pugilists, college presidents, tycoons, economists and politicians have all agreed that the history of the past is the prophecy of the future, but they have never failed to reconcile themselves to the thought that they, their affairs and their times are somehow exceptions.

Yes, the historian knows that man has experienced countless earlier depressions, and that at least those which have occurred during the periods of written history have been generally misunderstood. But the geologist, who, with Hutton, looks down the vista of the past to see "no vestige of a beginning" and scans the illimitable horizon of the future to discern "no prospect of an end," is alone fully cognizant of the true measure of antiquity which must be allotted to earlier depressions. Woman-like, Old Mother Earth keeps some of her secrets from even the geologist's ceaseless pryings. But he at least knows that earlier depressions are countless, that our globe enjoyed them even prior to the advent of life, and that life itself has waxed strong in ages of adversity and fallen into sorry ways in periods of plenty.

"The everlasting hills" is a phrase as irritating to the geologist as "all men are created equal" is to the sociologist. It is as poorly conceived as that fictitious "permanently high plateau" of stock prices. Tennyson tried to correct

its erroneous impression of stability by writing, "The hills are shadows, and they flow from form to form." The geologist can only reiterate that mountains of solid rock almost, if not quite, as high as the peak of the 1929 market have been elevated to haughty alpine grandeur only to be reduced to the ignominy of sea-level by the various agents of denudation, which are only slightly inferior to a bear operator in their ruthlessness.

The ocean has flooded the land not once but scores of times; and each inundation has written the record of its existence in the sedimentary deposits which it left behind.

There rolls the deep where grew the tree,
O Earth, what changes hast thou seen!
There, where the long street roars hath been,
The stillness of the central sea.

This is not only poetry but sound geology. The areas of Riverside Drive, Michigan Boulevard, Unter den Linden, the Strand and the Champs Elysée have all been beneath the "central sea" at repeated intervals. Even now Great Britain is sinking at a rate which is sufficiently rapid to effect nearly complete submergence within the next 40,000 years. Picture if you can a geographical map of Europe without the identification tag of the British Isles! Imagine the consternation of the Englishman 400 centuries removed who finds that at last the "waves rule Britannia" instead of the traditional converse!

Yes, even the continents have had their ups and downs, and, of course, their areas have changed remarkably throughout the past. They have presented bold, swashbuckling outlines when they stood high, but they have made sorry, attenuated showings during their periods of depression. Old Mother Earth has indeed suffered many vicissitudes. Her facial expression is one of great mobility. Although the changes

are ordinarily too slight to be noted by the casual observer, the geologist knows that during the long geologic past her face has been wrinkled where now it is smooth and unmarked where now it is deeply furrowed. As amanuenses to the "Old Lady" the geologists also know that she still entertains young ideas. She has surreptitiously lifted her face time and again. But the parable from the past is more clearly understood and more definitely encouraging when we remember that the earth has not only risen above her earlier depressions, but she has generally risen higher, rejuvenated and youthful after each succeeding deluge.

Protean Depression's innumerable offspring always include such relatively unimportant financially spoilt children as broken Mississippi Bubbles—in this present case Kreuger and Insull varieties—which are remarkably similar to such localized earth catastrophes as the collapse of volcanic peaks, which after all are more dangerous as lofty cones than as the resulting yawning calderas. But neither physical nor financial collapses are unmixed evils. The calderas which scar Mother Earth's broad weather-beaten face lend it character. The open financial wounds of the trusting public likewise soon give way to investment scars, which long remain to warn, even though they go unheeded. And who would insist that ancient Mount Mazama could have been in all its symmetry and towering height more inspiring than its incredible scar, the caldera of Crater Lake?

The record of earlier depressions is, of course, only in part a physical story. Even more pertinent comparisons may be drawn with the panics which life itself has encountered and survived Anteus-like, with strength redoubled.

If all geologic time is taken as 2,000,000,000 years and is represented on a clock dial as one hour, then 33

minutes of that hour elapse before the age of invertebrate animals is well under way. Even the beginning of the age of reptiles and the dominance of dinosaurs occurs only nine minutes before the minute hand reaches twelve. More surprising still is the fact that mammals, the dominant life of the present, have been the ruling animals of only the last paltry two and a half minutes of the hour. And man, commonly thought to have been present for 1,000,000 to 2,000,000 years, has only occupied the center of the stage a breathless two or three split seconds. In fact, man is such a newcomer that he has existed only while our geological clock has been striking the hour. But in spite of the fact that "depressions" occurred long before the advent of life, it is the effect of "hard times" upon organisms which particularly concerns man, the rankest of the untried *nouveau riche* among the animals, many of which for ages have lived in intimate association with man's relatively new acquaintance, Immortal Depression.

During the countless "depressions" which the world has been "allowed" in all those millions of years since the first successful organic synthesis, there has been an upward trending, though ragged, curve in the graph of the life complexity. In times of stress the weak organisms have died out, but the strong have always emerged from the troughs of trouble more powerful than ever. Modified to fit the changing environment, they have been ready to take advantage of the return of "good times."

The trilobites, marine crustaceans of the Paleozoic, constituted the Vanderbilts, Harrimans and Potter Palmers of the early part of that distant era. Incredible as it may seem, they were the first families then; and in their time there was no living thing to dispute their prominence, at least in the matter of intelligence. Nevertheless, in their

own life history they tell the old but ever recurrent story of the survival of the simple and the destruction of the specialized. The ornate members of the group (for even the intelligent have never completely resisted the urge of megalomania), like over-expanded individuals, families or industries (and universities as well), flourished in times of plenty, but they became extinct long before their lowly, generalized and conservative cousins had departed from the scene.

Primitive fish, living under the difficult conditions of elevating lands and dwindling, shifting streams characteristic of late Devonian times, were consequently greatly diminished in numbers. But a few ganoid types, with the true spirit of pioneers, used their fringed fins to painfully crawl from the desiccating ancestral pools to other less stagnant ones. These first air-breathing, partially land-living vertebrates not only gave rise to the amphibians—they originated a Paleozoic parable to the effect that, then as now, animals or industries which, instead of bowing to "hard times," use what resources they have to meet the changing situations are likely to be rewarded handsomely with the return of "prosperity."

The great refrigeration at the close of the Paleozoic era, with the attendant wide-spread glaciation, and the nearly world-wide crustal unrest, combined to make a time of great physical revolution, which was attended by organic disturbances of the most far-reaching sort. In fact, the destruction of life at this time was so great that the early geologists thought that all living things had been blotted from the face of the earth, although we now know that, severe as that "depression" was, a few strong, generalized types survived it. Their descendants repopulated the earth with new and more vigorous inhabitants.

Alcide d'Orbigny, as late as 1848, in studying the rocks of Europe came to the conclusion that the life of the earth had been annihilated not only at the close of the Paleozoic, but *twenty-seven times in succession*, and that twenty-seven distinct creations had repeopled the entire globe with new plants and animals, each new creation resulting in life more advanced than that which had just been blotted out. It is now known certainly that the thread of life, although stretched to extreme tenuity at many times, has never been broken. Life has indeed gone into its nadir even more often than the mere twenty-seven "geologic depression" times that d'Orbigny knew, but always it has returned to an ever more glorious zenith on the crests of new waves of successive early periods of prosperity.

The Mesozoic reptiles were megalomaniacs of the most confirmed sort. They were the masters of all the important habitats. The dinosaurs ruled the land, marine reptiles invaded and conquered the sea, and the "flying dragons," or pterodactyls, were lords of the air. But scurrying underfoot of the giant dinosaurs were a few mouse-like primitive mammals. They were subservient indeed to the gigantic masters of the moment, who, as is characteristic of the great (and especially the near-great), probably were totally unaware of the mammal's presence. But these small creatures, like some apparently insignificant individuals and many unpromising infant industries, had great potentialities. They proved their mettle at the close of the Mesozoic, when the earth went through another one of her really great "depressions."

This was, indeed, a time of revolution and of the "reddest" sort, for the reptiles, like Russian royalists, were nearly blotted out, and they have never again been particularly dominant. But the

small mammals weathered the hard times successfully. Out of their crude beginnings have come the greatly diversified and ruling mammalian types of to-day. They were one group which was not over-expanded at the time when opportune depression hit them. In effect, they sold the market short and made their fortune in the steady decline of reptilian values. The roots of that great modern spreading tree of mammalian types were firmly anchored in the very depression which was too drastic for the optimistic dinosaurs who, to the final crash, continued bullish on "Brawn not Brains, Inc."

Yes, the earth has enjoyed countless "depressions," the most wide-spread of these, paradoxically enough, being at times of great mountain building. And although some of the results have been so far-reaching that all life has seemed to have been blotted out, a few of the simple, sturdy stocks in actuality have always weathered the storm to build new and more glamorous family careers during the following period of inevitable world recovery. And for to-day's timid soul the most encouraging feature

is this—the new forms of life have always been more advanced than those whose places depressions made vacant.

The parables from out of the past are clear: All "hard times" are really "good times." Fortunes, families, mountain ranges and even continents rise out of "depressions"; all hard times are inevitably followed by "good times," which, in effect, are "bad times," inasmuch as in them family fortunes, individual initiative, national ideals and even lofty mountains are so weakened or reduced that they are likely to be completely destroyed or at least radically altered by the time the next "depression" is well under way.

Yes, Old Mother Earth has experienced many a depression. She is "enjoying" one now. But mother-like, she knows that mankind, her one unnatural offspring, is contrary enough to cry for the heady wine of plenty. And like the indulgent mother she is, once again she is preparing that universal pacifier—prosperity. It's an old story for her. She did it many times for her less articulate children before mankind was born.

THE RELIGIOUS AFFILIATIONS OF AMERICAN LEADERS

By Dr. C. LUTHER FRY

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DISCUSSIONS of the status of religion frequently lead to more heat than light. Truth comes hard in most fields but especially so in the realms of religion.

Some insight into the place of the church in the American social fabric can be gained from that hardy biennial of information—"Who's Who in America."¹ An analysis of the nearly 30,000 write-ups given in the 1930-31 edition, together with studies covering about two thirds of the names in the 1910-11 volume, shows that the religious affiliations of these American leaders are closely interrelated with their professions and occupations. Proportionately only half as many botanists and astronomers report any church connections as do educators or social workers. Moreover, in relation to the known distribution of the country's church membership, a disproportionately large number of people in "Who's Who" claim to be Unitarians, Reformed, Universalists, Episcopalians, Congregationalists, Quakers, or Presbyterians, while comparatively few say they are Methodists, Baptists, Disciples of Christ, Lutherans or Roman Catholics. Jews, too, appear very infrequently.

Certain types of religious beliefs are associated with particular lines of endeavor. Congregationalists and Unitarians, with their liberal tenets, especially excel as natural scientists, while Episcopalians lead among army and navy officers, and among architects and engineers.

¹ "Who's Who in America, A Biographical Dictionary of Notable Living Men and Women of the United States." Edited by Albert Nelson Marquis, Chicago. Vol. 6 and Vol. 16.

As most people are aware, "Who's Who" aims to include, as nearly as possible, brief life-sketches of the most notable living Americans in all parts of the world. The standards of admission divide the eligible into two classes. One comprises persons selected because of special prominence in various lines of endeavor, such as science, education, business and the arts. The other includes individuals chosen because of their official position and embraces all members of the Cabinet and of Congress, all United States judges and governors of states, all officers of the army above the rank of colonel and officers of the navy above the rank of captain, and all American ambassadors and ministers, as well as accredited foreign ambassadors and ministers residing in this country. In addition this arbitrary group includes American authors of books possessing more than "ephemeral" value, the bishops and chief ecclesiastics of the larger religious denominations and the heads of the larger universities and colleges and of certain well-known philanthropic, educational and scientific organizations.

There are some people who question the validity of any study based upon "Who's Who," on the ground that the list omits certain outstanding leaders and includes a number of third-rate ones. This does not, however, invalidate the present use of the volume. The main purpose of this inquiry was to ascertain the denominational affiliations of different classes of American leaders. For this purpose the individuals in "Who's Who" seem to constitute an adequate sample. There is no doubt that the volume contains many of the important

figures in contemporary American civilization. Glancing through the 1930-31 edition one runs across such outstanding personalities as Jane Addams, Nicholas Murray Butler, S. Parkes Cadman, Clarence Darrow, Mischa Elman, Simon Flexner, Cass Gilbert, Herbert Hoover, J. Pierpont Morgan and General John J. Pershing.

What proportion of the leaders in "Who's Who" claim to have any church connection? This question can be answered accurately because each candidate was asked among other things to report upon "religious denomination—if any." The returns show that out of the 29,623 write-ups analyzed in the 1930-31 edition, 16,629, or 56 per cent., reported denominational connection. This proportion is almost exactly the same as the average for the population as a whole. According to the 1926 Federal "Census of Religious Bodies," the number of persons over thirteen years of age listed on the membership rolls of the churches is equivalent to 55 per cent. of the entire population above that age. Apparently, American leaders do not differ from the rank and file in the extent of their church allegiance.

The relative number of individuals in "Who's Who" reporting a church affiliation has been growing very rapidly. An analysis of all the names from A to My in the 1910-11 edition of the volume shows that only 2,844, or 25 per cent., of the 11,355 names included said that they had a church connection, compared with 56 per cent. to-day. This increase is so rapid that the question arose whether during the period the method of obtaining the religious denomination of the candidate had been fundamentally altered, but correspondence with Mr. Albert Nelson Marquis, the editor of "Who's Who in America" revealed that it had not. These data would seem to indicate that during the last generation a church connection was looked upon with increasing favor.

In a further effort to compare the religious affiliations of the older and the younger generations of American leaders, several professional and occupational groups from the 1930-31 edition were analyzed by age periods to find out if younger men gave a denominational preference with less frequency than older people. Surprisingly enough, the results show that the percentage of individuals reporting a religious connection decreases as their age increases. The very old people record a denominational affiliation less frequently than any other age group. At least, this generalization holds for social and natural scientists, doctors, agriculturalists, and bankers and business men—the five groups analyzed in this fashion. It is not easy to account for this tendency, but it should be borne in mind that the rising generation of Americans are not as yet adequately represented in "Who's Who."

Almost as surprising as the large proportion of persons that claim a church connection is the small number who state that they are unbelievers. Out of the 29,623 names only seventeen took occasion to classify themselves in black and white as infidels, atheists, free thinkers or agnostics. In short, fewer than one of 1,700 leaders put themselves on record as being distinctly anti-religious. Ten of these militant non-conformists are writers; three are natural scientists; two are doctors; one is an artist and one is a mechanical engineer. In this connection it is interesting to note that of the thirty-two Presidents of the United States only three—Thomas Jefferson, Rutherford B. Hayes and Abraham Lincoln—did not claim a definite church connection.

RELIGION AND OCCUPATION

The data from "Who's Who" also tend to show that the more creative or mechanistic is a person's job the less the likelihood that he will be actively related

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to any denomination. Among actors, painters and sculptors only 23 per cent. claim a church connection, while among army and navy officers this proportion is 35 per cent. and among natural scientists 37 per cent. For editors and authors the ratio is 40 per cent., for social scientists 42, for doctors 50 and for architects and engineers 51 per cent. All other groups report higher proportions. Among the pillars of society—the politicians and diplomats, the judges and lawyers, the agriculturalists and the bankers and business men—from 54 to 61 per cent. report a church affiliation. Educators and social workers claim even higher percentages, with 63 and 64 per cent. respectively, but naturally religious workers show the highest returns, with 100 per cent. giving church connections.

These figures raise the question whether the religious affiliation claimed by the "Who's Who" fraternity is not, in considerable part, a matter of social pressure. Certainly a professor in a denominational college has a greater incentive to claim a church relationship

than has a sculptor, an army officer or a chemist.

Because of the peculiar influence of natural scientists in the modern world, it is interesting to contrast returns from different groups of scientific men separately. Among seven classes studied, astronomers show the smallest proportions, with only twenty-seven out of eighty-five, or 32 per cent., claiming a denominational relationship. Zoologists and biologists, including botanists and naturalists, report 36 per cent., while chemists show 37, physicists 40 and geologists 42. At the top of the list are mathematicians, with 52 per cent. giving a church connection. These figures support the belief that even the religious attitudes of scientific men are influenced by the particular type of research upon which they are engaged.

DENOMINATIONAL AFFILIATION

A person in "Who's Who" is as likely to report a church connection as is the average man on the street, but his denominational connection is usually quite

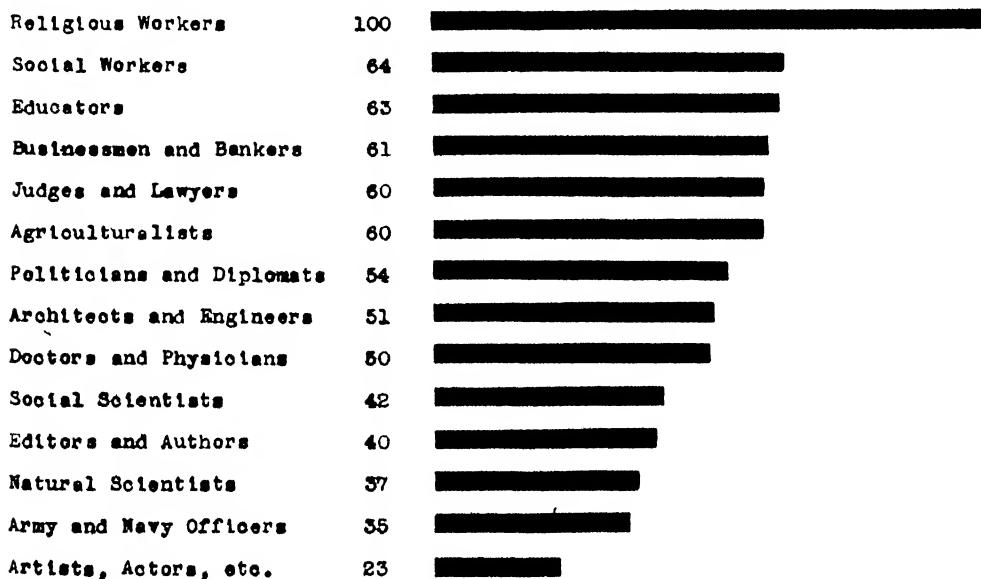


CHART I

PER CENT. OF PERSONS IN "WHO'S WHO" REPORTING CHURCH AFFILIATIONS BY OCCUPATIONAL GROUPS.

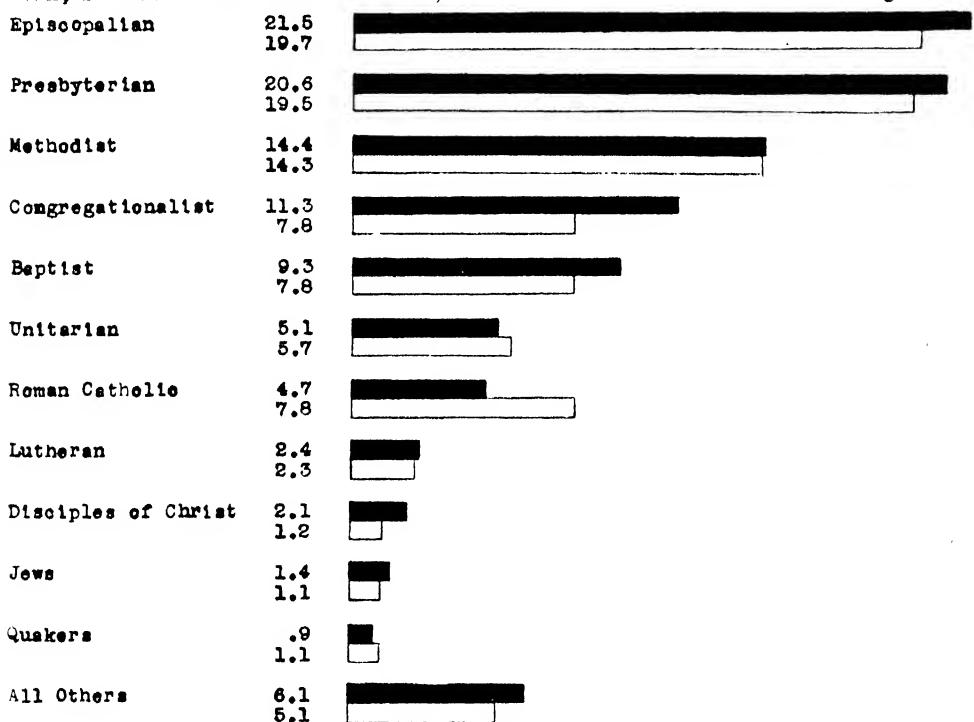
different. The great majority of leaders who report any church allegiance claim to be related to a handful of denominational groups. On the average, Episcopalians account for twenty-two out of every hundred; Presbyterians for twenty, Methodists for fourteen; Congregationalists for eleven and Baptists for nine. In other words, more than three quarters of the people who mention any denomination say they are affiliated with one of these five groups. Unitarians comprise 5.1 per cent. of the total and Roman Catholics only 4.5 while Lutherans report 2.4, Disciples of Christ 2.1 and Jews 1.3 per cent. All other denominations show smaller proportions.

For comparative purposes all the names from A to My in the 1910-11 "Who's Who" were also classified, to

learn how the denominational composition of these leaders has been changing. The results, which are presented in Chart II, indicate that Unitarians and Universalists, and especially Roman Catholics, have been declining in relative numerical importance, while other denominational groups, particularly Congregationalists, Disciples of Christ and Christian Scientists have increased comparatively rapidly.

DENOMINATIONAL REPRESENTATION IN "WHO'S WHO" AND THE POPU- LATION

The present representation in "Who's Who" of the different religious families does not at all correspond with the denominational distribution of church membership in the United States. This conclusion was reached through a de-



1930-31

1910-11

CHART II

CHURCH CONNECTION OF PERSONS IN "WHO'S WHO" REPORTING CHURCH AFFILIATIONS.

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tailed comparison of the relative numbers of church members in "Who's Who" and in the population as a whole. Using the data secured by the 1926 Federal religious census, the total number of church members over thirteen years of age was worked out for all the different white Christian denominations.² Negro bodies were entirely omitted, because the individuals in "Who's Who" are almost exclusively white. Jews, too, were left out of account, because this faith does not employ membership figures that are comparable with those of Christian Churches. On this basis the denominational representation in "Who's Who" in proportion to general church membership is shown on Chart III.

This comparison, which necessarily excludes Jews and which is further limited to thirteen church bodies having at least 100 representatives in "Who's Who," shows that the denominations concerned fall into four groups. At the top of the list are the Unitarians who are so far ahead of all the rest that they constitute a class by themselves. There are

²C. Luther Fry, "The U. S. Looks at Its Churches." New York; Institute of Social and Religious Research. 1929.

actually thirty-two times as many Unitarian representatives in "Who's Who" as the numerical size of the denomination would lead one to expect. The number is so large that the question arises whether a certain number of individuals have not classed themselves as Unitarians who have no active relation with the denomination. A candidate who was not associated with any church but who felt that a denominational connection was advantageous might well classify himself as a Unitarian both because this church is liberal theologically and because it enjoys social status.

The second class comprises a group of half a dozen bodies that have from 6.5 to 3.1 times as many representatives as might have been anticipated from their membership strength. In this group are the Reformed, Universalist, Episcopalian, Congregational, Quaker and Presbyterian churches. These denominations, together with the Unitarians, enjoy a preferred status: twenty-two of the twenty-nine American Presidents claiming church connections have been affiliated with these bodies.

The next class includes, in addition to Christian Scientists, such old-line

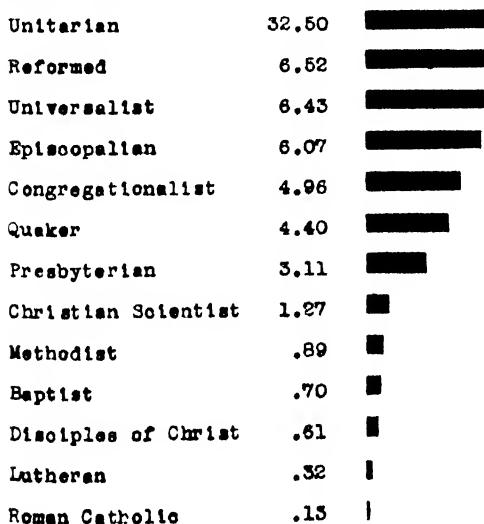


CHART III

DENOMINATIONAL REPRESENTATION IN "WHO'S WHO" IN PROPORTION TO GENERAL
CHURCH MEMBERSHIP.

Protestant denominations as the Methodists, Baptists and Disciples of Christ. Among this group the actual representation in "Who's Who" ranges from 1.27 to 0.61 times the expected number. Only six presidents were members of these denominations.

At the bottom of the list are Lutherans and Roman Catholics, who report, respectively, 0.32 and 0.13 per cent. of their membership quotas.

The proportionate representation of the Jews can also be ascertained, but through a somewhat different method. The last religious census found 4,081,000 persons of Jewish faith living in communities in which local synagogues are situated. Even assuming that this figure represents the total Jewish population of the country, it means that at least 3.57 per cent. of the inhabitants of the United States are Jews. On this basis one would expect the same proportion of Jews to appear in "Who's Who," but as a matter of fact only 218, or 0.74 per cent., of the names analyzed claimed to be Jews.

As a further check upon the Jews a special study was undertaken of the people who did not report religious connection in "Who's Who," even though they are listed as Jews in the "American Jewish Yearbook" or "Who's Who in American Jewry."¹⁸ It was found that there were 432 such persons, compared with only 218 who stated they were Jews. In other words, not more than a third of the individuals of Hebrew extraction claimed to be connected with a Jewish synagogue. Out of sixteen architects and engineers who are racially Jewish not one claimed any religious affiliation, while only nine out of fifty-five scientific men falling into

this category classed themselves as Jews. Of course, it may be that Jewish leaders have broken with their religion to a greater extent than is the case among Christians, but it is also true that certain individuals may hesitate to classify themselves as Jews because such an admission would be considered a social liability. At all events those professing the Jewish faith are distinctly under-represented in "Who's Who."

It is scarcely a matter of chance that the denominations which are least represented in "Who's Who" are the Jews, Roman Catholics and Lutherans, that have comparatively large numbers of foreign-born adherents. There has never been a President of the United States who was a member of any of these bodies.

DENOMINATIONAL REPRESENTATION BY OCCUPATION

It has often been claimed that what a person says he believes on Sunday has no relation to his occupational activities during the week, but is this belief well founded? Certainly the information assembled by this inquiry leads to the conclusion that there is a definite relationship between a man's profession and his profession of faith. The results are summarized in the accompanying list. As might have been expected, no Quakers are found among army and navy officers, and no Christian Scientists among the doctors and physicians.

The Puritanical position which holds that the theater is sinful is reflected in the fact that Baptists and Methodists make their poorest showing among actors, sculptors, etc., while Roman Catholics, Lutherans and Episcopalians, who have long been patrons of the theater, rank high among actors.

The denominations that report comparatively large numbers of politicians are the bigger bodies that have strong voting strength—the Baptists, Meth-

¹⁸ "American Jewish Yearbook," Vol. 33, 5692 (1930-31) Philadelphia, Jewish Publication Society of America; "Who's Who in American Jewry," 1928, New York, The Jewish Biographical Bureau, Inc.

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Makes best showing among	Denomination	Makes poorest showing among
Educators Politicians	Baptists	Architects, engineers Artists, actors, etc.
Actors, artists, etc. Army and Navy officers	Christian Scientists	Doctors (None) Social workers (None)
Natural scientists Social scientists	Congregationalists	Doctors and physicians Army and Navy officers
Agriculturalists Social scientists	Disciples of Christ	Actors, artists, etc. Army and Navy officers
Army and Navy officers Architects and engineers	Episcopalians	Natural scientists Agriculturalists
Actors, artists, etc. Politicians	Lutherans	Judges, lawyers, etc. Army and Navy officers
Educators Politicians	Methodists	Architects and engineers Actors, artists, etc.
Business men, bankers Judges, lawyers	Presbyterians	Army and Navy officers Actors, artists, etc.
Agriculturalists Social scientists	Quakers	Judges, lawyers (None) Army and Navy officers (None)
Editors, authors Agriculturalists	Reformed	Social workers Natural scientists
Actors, artists, etc. Politicians	Roman Catholics	Agriculturalists Social scientists
Natural scientists Social workers	Unitarians	Politicians Army and Navy officers
Editors, authors Judges, lawyers	Universalists	Social workers Agriculturalists

odists, Lutherans and Roman Catholics. Denominations like the Roman Catholics, Episcopalians and Universalists, that are largely concentrated in cities, naturally claim relatively few followers among the agriculturalists.

Some denominations show much greater occupational versatility than others. Presbyterians, for example, are represented in each field almost equally well. Relatively they are most numerous as bankers and business men, but with the exception of the arts—acting, painting, sculpture, etc.—they make

much the same showing among the other occupational and professional groups.

Two denominations that are distinctly liberal in theology—the Congregationalists and the Unitarians—rank especially high among natural scientists, while the Roman Catholic Church, with its rigid set of beliefs, is very poorly represented.

CHECKING THE FINDINGS

The findings for the natural scientists afford the opportunity of testing the significance of the data presented in this study. Some months ago Dr. Harvey

C. Lehman and Dr. Paul A. Witty published an article on "Scientific Eminence and Church Membership" which employed a distinctly different method from the one adopted in this inquiry. Instead of relying upon the names that happen to appear in "Who's Who" these investigators hand-picked their candidates. Using the 1927 edition of "American Men of Science," the biographical dictionary edited by Professor J. McKeen Cattell, they selected from among the 13,500 names listed there the 1,423 that according to carefully worked out tests have achieved notable success in their particular fields. They then looked up each one of these individuals in "Who's Who" in order to find his religious affiliation. During this process a sixth of the names had to be eliminated because they were not listed in "Who's Who." This left 1,189 eminent scientific men whose church connections, if any, could be ascertained. The advantage of this method lies in the fact that only unusually distinguished natural scientists were included. No person was counted merely because he happened to hold an official position. The "stuffed shirts" were entirely eliminated.

How do the results of that inquiry compare with our own? Lehman and Witty found that only 25 per cent. of eminent scientific men claimed any church connection, compared with 37 per cent. of the natural scientists in "Who's Who." Obviously, highly distinguished scientific men report a church connection even less frequently than the findings of the present inquiry would indicate. With this exception the two sets of findings agree very closely.

Comparative figures showing the proportionate representation of scientific

* "Scientific Eminence and Church Membership," *The Scientific Monthly*, December, 1931, p. 544.

men among the different denominational groups are given in the following table:

Denominations	Lehman and Witty	Fry
Unitarians	81.40	64.38
Congregationalists	9.31	9.55
Friends (Quakers)	6.60	7.20
Episcopalians	5.70	3.55
Presbyterians	3.05	3.20
Methodists	.44	.89
Disciples of Christ	.29	.41
Baptists	.24	.49
Lutherans	.20	.25
Roman Catholics	.05	.04

This comparison reveals that Lehman and Witty found 81 times as many eminent scientists classed themselves as Unitarians as might have been anticipated from the membership strength of that denomination, while our "Who's Who" analysis shows 64 times the expected number. For most denominations the correspondence between the two series of findings is extraordinarily close.

In general both sets of figures tell the same story—liberal Congregationalists and Unitarians at the top and conservative Lutherans and Roman Catholics at the bottom. Moreover, the most striking differences between the two results are owing to a correction adopted in this study that was not employed by Lehman and Witty. As every one knows, certain denominations, notably the Methodist and the Baptist, have a very large number of Negro members. It hardly seemed fair to include these members of colored bodies when computing the proportionate representations of the two denominations. This, therefore, is the reason that our computations give the Methodists a rating of 0.89 and the Baptists of 0.49 when the comparable figures of Lehman and Witty are only 0.44 and 0.24, respectively.

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The materials collected by this study tend to prove not only that a man's religion is closely associated with his occupation or profession but also to support the general thesis developed by André Siegfried in "America Comes of

Age"⁵ that the dominant tradition in this country is distinctly Anglo-Saxon and Protestant.

⁵ André Siegfried, "America Comes of Age," New York; Harcourt, Brace and Company, 1927.

DETAILED DENOMINATIONAL REPRESENTATION IN "WHO'S WHO" IN PROPORTION TO GENERAL CHURCH MEMBERSHIP*

Occupation	Episcopalian	Presbyterian	Methodist	Congregation-alists	Baptist	Unitarian	Roman Catholic	Lutheran	Disciples of Christ	Quakers	Reformed	Universalist	Christian Scientist
Religious workers	3.69	3.13	.98	3.64	1.14	14.38	.21	.65	.73	1.20	1.41	7.86	1.02
Judges, lawyers	7.16	3.40	.90	4.04	.61	36.25	.14	.17	.76	2.00	.49	7.14	1.00
Doctors, physicians	8.09	3.29	.72	3.43	.60	41.25	.10	.25	.44	2.40	.29	5.71	—
Educators	3.77	3.20	1.20	7.00	.84	30.00	.04	.26	.70	6.80	.59	4.29	.52
Editors, authors	7.76	2.61	.68	4.78	.49	39.38	.15	.20	.50	4.80	.99	15.71	2.98
Architects, engineers	9.59	2.73	.49	5.70	.30	60.63	.09	.20	.23	6.40	.15	3.57	.85
Business men, bankers	8.09	3.66	.68	4.28	.47	30.00	.13	.20	.47	5.20	.43	4.29	1.63
Actors, artists, etc.	9.13	1.77	.44	3.57	.20	52.50	.23	.66	.15	6.40	.34	2.14	7.25
Politicians, diplomats	5.96	2.95	1.13	3.43	.80	15.00	.19	.45	.85	3.20	.38	6.43	.72
Social workers	4.24	2.70	1.12	7.26	.63	63.12	.05	.24	.20	9.60	—	—	—
Army & Navy officers	14.54	2.20	.50	2.04	.41	7.50	.18	.16	—	—	.44	4.29	4.33
Natural scientists	3.55	3.20	.89	9.55	.49	64.38	.04	.25	.41	7.20	—	5.71	.89
Social scientists	5.00	2.78	1.11	8.52	.48	36.88	.03	.20	.96	10.40	.48	5.00	.69
Agricultural group	2.68	3.17	1.05	8.04	.52	35.00	.03	.25	1.26	2.40	.70	—	3.42
All others	8.91	2.51	.59	2.74	.56	45.63	.11	.30	.64	2.40	1.84	14.29	1.06
Total . . .	6.07	3.11	.89	4.96	.70	32.50	.13	.32	.61	4.40	6.52	6.43	1.27

* This comparison is limited to the Christian denominations having more than 100 representatives in "Who's Who in America."



CAPTAIN JOHN SMITH'S MAP OF VIRGINIA

THE "NOBLE SAVAGE"

By Dr. ELSIE MURRAY

ITHACA, N. Y.

THE naïve faith in the "natural man" which ran like wildfire through the eighteenth century has baffled the curious of more than one generation. The strange obsession that, uncorrupted by kings, clothes, parliaments, printing or ceramics, man was or would be a wholly admirable creature must somewhere have had a nucleus of fact. No mere academic whimsey (Van Loon and Cabell to the contrary) ever possessed such potency. Who launched this myth of the "noble savage"—destined to intrigue the wits of savants and tale-mongers for two centuries, and ultimately change the face of Europe?

Not long since, as I thumbed the stained and tattered pages of a small calf-bound copy of John Smith's "True Travels," a sudden light broke in on the enigma. The little volume provides rough going for the twentieth century reader. A truer cross between "Ulysses" and a schoolboy version of the "Aeneid" it would be difficult to figure. Brave the Joycean intricacies of its style, however, and one fact rises clear above the wordy welter. The *Sasquesahanoughs*, vestiges of whose culture and long occupation of the Susquehanna have lately been retrieved near Safe Harbor, were the originals of the "noble savage"; and Captain John Smith of Jamestown the artist who first limned their portrait, in the year 1609!

"Such great and well-proportioned men," writes Smith, "are seldom seene; for they seemed like Giants to the English, yea and to their neighbors, yet seemed of an honest and simple disposition." As for their speech, it is "the strangest in all these countries, for their language it may well beseeme their pro-

portions, sounding from them as a voyee from a vault." The few phonetic samples submitted, notably *kekataought-assapooesksku*, the numeral for ninety, and *necuttwevnquaough*, the slightly less appalling equivalent for a thousand, would appear to furnish ample warrant for the last reflection.

The garb and adornment of these natives set even the traveled Elizabethan gaping. For, unlike the subjects of Powhatan, they were clothed in "the skinnes of Beares and Woolves, from which the eares, nose, teeth, and paws still dangled." One had the head of a wolf hanging on a chain for a jewel, another a string of white beads weighing six or seven pounds, a third a green and yellow snake hanging from a perforated ear. Yet more astounding, in size and contour, were the tobacco-pipes they carried. Three quarters of a yard long and more, Smith describes them, "prettily carved with a Birde or a Deere, or some such devise at the great ende, sufficient to beat out one's braines!"

A singular item in the picture arrests the attention of the reader. Smith, in common with many of the early explorers, reports the epidermis of the native as white at birth. In the adult, however, it was customarily decorated with stripes, or tattooed totem animals, or stained cinnamon brown by a decoction of roots and oils, for protection against the attacks of insects or climatic change. Regrettably, the recipe for the cosmetic by which the latter object was effected is inadequately recorded. It might have made the fortune of some latter-day chemist.

Penetrate further into the "General

Historie of Virginia" and conviction grows. Here was a source-book of inestimable riches—for all its execrable English. The golden-agers, the back-to-naturists, and fanatics of equality—the Rousseaus, Swifts, Defoes, Montesquieus of many generations—must have dug pertinent facts and fancies from its pages. Even the youthful Milton may have found treasure-trove in the "True Travels." The revels of "Comus" find their prototype in the fanciful sketch of Pocahontas' *mascarado* with her maidens. The Lady of the Masque herself, chaste and imperturbable, may derive, paradoxically, from the Indian princess, "Powhatan's dearest daughter," whom "darkest night could not affright, nor coming through the irksome wood."

The converse is, of course, as credible. Smith, the old rascal—the original Trader Horn of the Americas—was taxed even in his own day with having "writ too much and done too little." Out and out Elizabethan, with an equal verve for phantasy and fighting, he may well have warped his tale to a literary model. The account of the *mascarado* above referred to, savoring now of Malory and the "Mort d'Arthure," and again, threatening to out-Bottom Bottom with its "excellent ill varietie," affords ample warrant for the last assumption. The finale of the *mascarado*, with Pocahontas' "nymphs," clad in green leaves and otters' skins, "crowding, pressing and hanging about, crying 'Love you not me, love you not me!'" is a veritable travesty of Parsifal's temptation, with the circle of flower-maidens closing in seductively about the hero.

So much for romance! The captain's account of the sixty "giant-like" Susquehannocks who came down to greet him—sun-worshippers, disposed to bend the knee before his resplendent doublet and plumed headgear—is of course on an utterly different footing. It is pos-

sible, to be sure, that the mental yard-stick on which Smith laid off the length of the carved stone pipes of his visitors, the leg-span and stature of their chiefs and *werowances*, may have lacked precision. On many counts, however, his description checks with data from quite independent sources.

Sober seventeenth century narratives of Swedish missionaries on the Delaware, of Jesuit Fathers marooned among the Hurons on the St. Lawrence, corroborate the Captain's jottings. Even young Alsop, who turned his back on Puritan England to gather matter for a "Character of Mary-Land," naively confirms many points in Smith's description. The amazing stature, the personal dignity and courage of the group of *Ongwe Honwe*¹ who until almost 1700 kept their grip on the great waterway of the Susquehanna—in the face of repeated thrusts from Senecas, Oneidas and white intruders—stands well documented on the page of history.

Nor is archeological evidence wanting to sustain the verbal. Skeletal remains of great size, stone pipes carved with animal and human heads, and pottery of rare design have been unearthed on Susquehannock sites, both at Safe Harbor, near the Chesapeake, and on the northern reaches of the Susquehanna—at old Tioga Point on the Pennsylvania border, and along the New York State tributaries. For Captain Smith's map, it will be recalled, locates five *Sasquesahanough* settlements to the northward—Testnigh, Attaock, Utchowig, Cepowig and Quadroque—unvisited, to be sure, but reported by trusted Indian advisers.

Closer scrutiny of the evidence, however, is needed to convince the cautious; and the witnesses form so picturesque a crew, no pretext to hale them into court can be rejected. First of all, in point of time, come the Swedes. Sent over-

¹ The name applied to themselves by the Iroquoian group as a whole, signifying "real men."

seas to actualize the dream of a New World state outside the vicious circle of religious wars, they bought land of the Indians, built Fort Christina on the Delaware, and began a lucrative trade with the Susquehannocks. Christine, to be sure, had less of a finger in this colonial pie than local patriots are prone to assume. In 1639, though technically queen, the gifted and eccentric daughter of Gustavus Adolphus was still in her early teens, and the guiding hand in the enterprise was presumably that of Oxenstiern, her minister.

In "Nya Sverige," a grandson of the first pastor-missionary of the colony, Johan Campanius Holm, preserves for us a vivid picture of the "Minques."² Commanding a rich inland country, this aboriginal "nation," in exchange for axes, cloth and kettles, offered the furred skins of the beaver, fisher and mink—all greatly in demand among the wealthy burghers, princes and prelates of the Old World, to edge their sleeves and line their ceremonial robes. The palisaded "fort" occupied by this tribe was situated on a high mountain, distant twelve miles (equivalent to 93 English ones) from the Delaware, across a difficult country, full of sharp gray stones and hills and morasses. The occupants of the fort were renowned for their warlike character, "having made the surrounding tribes subject and tributary. . . . They are a tall people," the text continues, "not frightful in appearance. When they are fighting they do not attempt to fly (the usual tactics of the Indian) but all stand like a wall as long as there is one remaining"; and more of the same admiring and respectful tenor.

The accounts left by the Jesuit Fathers and La Salle are no less adulatory. From 1640 to 1679 the "Relations" are

² A generic and unflattering term signifying "stealthy adders," applied often indiscriminately to all their aboriginal neighbors by the Dutch and Swedes.

full of the exploits of the *Andastes* or *Gandastogues* (the French name for the Susquehannocks, signifying "people of the curved roof-pole"). The Fathers took to themselves no little credit for a Susquehannock convert, one Arenhouta; through whose offices, they claimed, this mighty group of warriors was drawn into alliance with the Hurons against the restive and intractable Five Nations. If the incident is not overrated, the Christian Arenhouta played indeed a fateful rôle in the annals of his tribesmen. For the mortal ire of the Iroquois was roused by the Huron-Andaste compact, and the destruction of the latter group forthwith resolved upon.

In the relation of the retaliatory raids that followed, the number of warriors in the Susquehannock forts, their use of European modes of defense, of guns and cannon, are meticulously set down. In the pages of the Jesuits, fleets of war canoes dash up and down the river, from headwaters to the bay and back, at a speed excluding any doubt (in the minds of those who know the course) of the skill and intrepidity of the boatmen. As for the further exploits recounted in these annals—of the band of sixty Andaste boys who vanquished as many adults, of the warrior who, single-handed, repulsed a raiding party of 400 Oïogouens—their parallel is discoverable in the chronicles of Sparta only—with which, no doubt, the Fathers were sufficiently familiar.

Less unimpeachable but vastly more diverting is another contemporary record—the account of the "wild and naked Susquehanocks," appended by young George Alsop to his "Character of the Province of Mary-Land," above cited, printed in 1666. First of the super-salesmen of America, Alsop was despatched to the colony under a four years' indenture, commissioned, it appears, by Lord Baltimore or his agents to compose a blurb on Maryland. Fru-
gal Roundhead had replaced snuff-

taking Cavalier in Old England, the consolatory offices of nicotine in a "depression" were as yet unexploited, and in 1649 the bottom had literally dropped out of the tobacco market. The young colony across the seas, whose main dependence was on this staple, was in distress. Laborers and colonists were difficult to attract, and the youthful poetizing Alsop was picked for the job of "selling" Maryland.

Tobacco advertisements were luckily not in the bargain. For young George, replying to a brotherly request from across seas for "some Smoak," remarks with acerbity that the only office of the latter is to "exorcise or affright the Devil." Yet here if ever was a man whose inmost being craved the solace of a pipe—if one may risk an opinion on the portrait which serves as frontispiece to his little volume. Pensive, misanthropic, devoid of any shred of humor, his face looks out from its frame of wavy locks, on a world whose chaos, he mournfully declares, is "matched only by his own soul's confusion."

After a "blowing and dangerous passage" of five months, however, Maryland, "in all her Greene and fragrant mantle of the spring," looked very Eden to the young apprentice. His spirits rose. Euphuistic and yeasty in diction by temperament or training, never using one word when six would serve his purpose, he achieves, for all his verbiage, an unforgettable picture of the province. Its sports of hunting and fishing, the fifty-pound turkeys that lurked in its woods, the innumerable wild fowl that rose from the bay like a great dark tidal wave, all receive fitting tribute.

Inserted in his "Land-Skip of Lord Baltimore's Plantation," appear two Adam-and-Eve-like figures of the aborigines (obviously cribbed from the Sistine ceiling). Accompanying them are amusing sketches of the various

species that followed Noah into the Ark—boar, wolves, foxes, raccoon, a bear testing his claws on a palm-tree. The text takes pains, however, to assure the future visitant that the "staring visages of the wilde Animals need not affright him," that he may walk in the open "with as little fear of being externally dissected as though he were in his own dwelling." The ladies alone of Maryland appear to have fallen short of the writer's expectations. He records them talkative, insensitive to the charms of courtly rhetoric; and subscribes one of his effusions plaintively, "From the Chimney-corner, on a low cricket, where I writ this in the noise of some six women."

Although Alsop modestly declares that his observations were made in the main from the safe shelter of a tree, his opportunity for noting aboriginal traits was certainly exceptional. The four years of his indenture were served on the northern outskirts of the province, on the estate of one Stockett, whose special office was the issuing of passes to Susquehannocks who wished to approach nearer to the settlements, across the bounds set by treaty.

"The most noble and heroick Nation of Indians in the confines of America," our young apprentice pompously pronounces them; "cast in the mould of a most large and warlike deportment, the men being for the most part high in latitude, their voyce large and hollow, as ascending out of a cave, their gate and behaviour strait, stately and majestic, treading on the earth with as much pride, contempt and disdain to so sordid a Center as can well be imagined from a creature derived from the same mould and Earth."

This impressive and Miltonic picture is marred by one blemish only. The Susquehannock, Alsop avers, worships the devil himself, sacrificing to him a child every fourth year. Cannibalistic

rites are furthermore declared to attend the war raids of the group. The accusation gives us pause—it appears to have been overlooked by the original underwriters of the "noble savage." It is true the Susquehannocks were sometimes known as the "Demon People," *Askikouannhe*. It is unclear, however, whether this name refers to their size and fierce and aggressive character or whether it derives merely from the many caves and waterfalls along the course of the Susquehanna; for these natural features, in the Indian cosmogony, are the peculiar creation of the evil one.

Boocootawanough, we know from other sources, they were also called—destroyers, or as some versions have it, flesh-eaters. With all the Konoschioni, however, the eating of human flesh, it will be recalled, was a sacred rite—a kind of eucharist. For their animistic (and totemistic) beliefs made it wholly likely that the spirit of a valiant enemy would be assimilated with his flesh and blood. Eloquent expression of some such conviction may be detected in the statement of the old chief, who declared that brandy must be made of hearts and tongues, since after tasting it his courage was always higher, his speech more fluent.

This peculiar defect in manners or in morals, noted by Alsop, appears somehow to have escaped the notice or the censure of the early romanticists and back-to-naturists. For the verdict on the superiority of the Susquehannock, both over his own kinsmen and over the effete city-dweller, has come down the centuries to us virtually unchallenged. To verbal evidence, the mute witness of archeological finds on the lower and upper reaches of the Susquehanna, above referred to, is steadily accruing. Many years ago, in northern Pennsylvania, a burial ground was opened at *Teaoga*—believed to have been the site

of Champlain's palisaded village of Carantouan, later the southern door of the mythical Long House of the Six Nations. Skeletal remains of great size, in a state of preservation indicating long interment, were unearthed. Buried with them, in primitive fashion, were artifacts of rare design: carved stone pipes, turtle-shell rattles, jars ornamented with intricate geometric patterns and extraordinarily modeled human faces—whatever the dead might need on their long journey.

In the last two years, at Safe Harbor, these remarkable findings have been duplicated. Huge stone pipes with carved animal heads, bone combs adorned with human figures, fish-hooks and harpoons of unusual pattern also, with beads, wampum and pottery of a vast range of sizes are among the spoils. No vestige of doubt remains that the feminine artisans of the tribe (for Susquehannock craftsmen were always female) were as preëminent along artistic lines as its warrior huntsmen were renowned in all that relates to physique and action.

The mystery deepens. Here was a splendid people, highly endowed, adaptable, adopting white men's ways and implements (where their superiority was patent), yet destined like their prototypes, the primitive Crô-Magnon, to disappear from the earth, replaced by inferior stocks.

A closer scrutiny of the records, however, resolves in part the enigma. The Susquehannocks were fairly caught in the steel trap of civilization. Their very avidity for white man's goods—guns, axes, cannon—the numerous contacts with white soldiers and traders that resulted, exposed them to sudden inroads of new diseases (notably smallpox in virulent form), with no chance for a gradually acquired immunity. Furthermore, their beloved river was a key site, at once an important artery of the fur

traffic, and far too easy an avenue of approach to the low-lying, defenseless shores of its great estuary, the Chesapeake. Coveted on the one hand by their jealous kinsmen to the north, it was the pivot also of schemes for defense, for territorial and commercial expansion of the Penns, the Baltimores and the neighboring colonies to the east—New York, Delaware and “New Jarsy.”

Fairly early in the seventeenth century, it appears, Maryland saw the advantage of using the Susquehannocks (strongly fortified on the lofty crags of their great waterway) as a buffer against attacks from the Senecas, Cayugas and Oneidas. For the imperial ambitions of the latter were already sprouting, and swift raids on southern tribes along the bay, or on defenseless colonists, kept the nerves of the province in a continual twitter. A treaty pledging eternal friendship, sealed by a silver medal on a black and yellow ribbon, long cherished, was therefore made; and guns and officers for the fort on the lower river promised. Presently, however, there arose on the horizon a new menace—William Penn, the Quaker, seeking a foothold on the Susquehanna for his co-religionists.

Owing either to the sheer muddleheadedness of the charter-granting Stuarts or to their geographical ignorance, a spirited boundary controversy between Baltimore and Penn was shortly under way. The site of the Susquehannock fort was the pivot of the dispute, which dragged on far into the next century. Traders' affidavits that the fort of the boundary agreement lay to the southward, at the mouth of the Octoraro, were assiduously garnered by the Penns; while Lord Baltimore rewarded with a manor one Augustine Herrman, on whose beautifully executed map of 1670 the disputed fort appears far to the northward, on the west bank, near the mouth of the Cone-

wago. Impartial opinion, it is fair to add, locates the original fort midway between these two sites, on the east bank, possibly on Turkey Hill.

Now whether the Susquehannocks—a cat's-paw to white ambition—were bribed by Baltimore's agents to shift their location from a lofty crag on the left bank to a low-lying, less strategic point on the right, is not clear. It is known that Maryland presently, in a spasm of fear, turned on her former allies (whom a sudden onslaught of the Senecas had driven down the Bay and up the Potomac and the Piscataway). The last band of the Susquehannock warriors, among them that picturesque old irreconcilable, Hochitagangete or Barefoot, along with five other sachems, were ignominiously slaughtered. Was it poetic justice that a few years later the coup of the astute Penn succeeded and Maryland lost a twenty-mile slice off her northern borders—the very heart of the old Susquehannock territory?

Thus ingloriously, about 1676, the extinction of the Sasquesahanoughs appears to have been effected. But did the originals of the “noble savage” actually perish from the earth, leaving no vestige except the eulogies of their admirers and the funeral pottery of their dead? Closer scrutiny of the records engenders doubt. Like many primitive and imaginative people, the Iroquoian cherished the peculiar custom of blood-adoption. With equal faith in heredity and environment, in the power of the totem and in sympathetic magic, they were wont to fill the gaps left by war losses with the bravest captives; replacing thus a missing brother, father or husband, as the case might be. Old maps and records show that at least a hundred of the finest Susquehannock warriors were thus disposed of, partitioned among the Oneidas, Onondagos, Senecas and Cayugas—each canton vying with the others for her share of living booty.

Little imagination is required to trace the finger of these transplanted Susquehannocks in the Confederacy's later history. A peace was presently patched up between the Iroquois and the neighboring colonies; but resolutely, for a hundred years and more, the intrusion of white settlers along the Susquehanna was resisted. Is it fanciful to discern in the eloquent, defiant speeches of the great sachems dispatched from Onondago to the conferences at Albany, Lancaster and Philadelphia the determination of the Susquehannock braves to exclude white intruders from their hereditary hunting-grounds in central Pennsylvania? For many years an Iroquoian agent was stationed at Shamokin (now Sunbury) for the express purpose of regulating liquor traffic and fore-stalling the careless signing away of land-rights to representatives of the wily Penn or Andros. "The land lasts always, but the goods waste soon away," was the oft-repeated caution of the sachems (Susquehannock, shall we doubt?) to young hotbloods, when colonists came seeking new concessions.

So much for eighteenth century evidence of Susquehannock wit and resolution, absorbed but unsubmerged in the Confederacy. Even to-day, it is said, in

certain of the Pennsylvania and New York State reservations, a sprinkling of large-boned men, of stature more than average, suggests the survival and out-cropping of certain dominant physical traits of Captain Smith's Sasquahannoughs.

A subtler dénouement, however, intrigues one's fancy. Not long since, a visiting Englishman excited much derision by remarking that in all American colonial stock there must be an infusion, however slight, of Indian blood. Perusal of old documents lends color to this hypothesis. Casual interbreeding at trading-posts of course enters into the picture. But far more arresting are the multiplying tales of white captives, brought up in Indian long houses, sending back their descendants to the colonies. Who knows but that the finest of our native Pennsylvania stock contains a tincture of old Susquehannock? Virginians boast of their descent from Pocahontas. As interesting escutcheons might be fashioned if all good Pennsylvanians ransacked their family letter-files and journals for evidence of a blood-strain of their gifted predecessors—the artist potters and intrepid hunters of the Susquehanna—the originals of the "noble savage."

GRASSES AND MAN

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HUMAN life has been and is more dependent upon grasses than upon any other group of living things.

GEOLOGIC GRASSLANDS AND PRIMITIVE MAN

The Miocene epoch is characterized by the formation of extensive grassland areas which replaced the swampy vegetation of the preceding epochs. It also presents a world-wide prevalence of the ancestors of most grass-eating (herbivorous) mammals. These animals, by contrast with their weak-toothed and short-limbed ancestors, possessed long-crowned and strong teeth adapted for grinding grass and relatively long feet adapted for running over hard and dry grassland in search of water and to escape from enemies. The abundance of grass favored the multiplication of the herbivorous mammals. This in turn furnished an increased food supply for flesh-eating (carnivorous) animals, and, as a consequence, these also increased in number. The grasses were thus the controlling influence in the Age of Mammals.

The human importance of this fact is that primitive man was obliged to follow these animals—his almost exclusive food supply—as they wandered from grassland to grassland. Even after he domesticated certain of the mammals—the horse, ox, sheep, goat, pig and dog—he continued to be a nomad because he still had to herd these animals from one favorable grassland to another. Virtually all primitive men were characterized by this wandering life until certain of them, in various parts of the earth, observed that several of the grasses which their animals ate produced seeds which were not only edible food but

were capable of remaining so for a considerable time. Man, in other words, discovered that he could store good food for himself. Thus man ceased to be dependent entirely for his food upon his animals, which in turn fed upon the pasture grasses. The cereal grasses became a direct portion of man's diet and furnished him with some nourishment which he could obtain by staying in one place.

By thus becoming a grass-eater, man changed his life from that of a nomad to that of a settler. This change was tremendously important for mankind of all times. There have not been any beginnings of civilization apart from agriculture. The earliest known agriculture was the cultivation of the cereal grasses, which resulted in the conservation of the human energy formerly wasted in roaming, in a sense of ownership, in the development of tools and appliances from various metals, in periods of leisure time during which thought, language, literature and art could make their first appearance in human life, in the beginning of settled and social life, and, in fact, in the introduction of most aspects of civilization.

Every known primitive civilization was built directly upon one or another of the cereal grasses, sometimes supplemented with pasture grasses.

CIVILIZATION IN ASIA

In Japan, millet and rice were cultivated since primitive times.

Human life in China, in the Indian Archipelago, in the Malay Peninsula and in the Philippine Islands, was dominated by rice.

The primary food of the Aryans in northern India consisted of rice. Bar-

ley and sugar cane were also used extensively. The Aryans had pasture-lands on which they grazed their animals which furnished meat and the means of transportation. Guests and gods were honored by being seated on grass mats. To their gods, they offered up roasted grain (probably barley) and cooked rice.

The Proto-Nordics were an entirely pastoral people. They were nomadic and followed grasslands in central and western Asia. The invasions of the Huns, Tartars and Mongols were motivated by the necessity of finding new grasslands for their animals.

In Persia, wheat was the chief constituent of human diet.

In Babylonia, about 3100 B. C., land was paid for by bronze and by grain. At about 1400 B. C., there was an appliance for plowing the land and sowing the seed of grain in the same operation. In 450 B. C., the historian Herodotus wrote: "The soil is peculiarly adapted to grain; no fruit trees are grown; only barley, wheat, and millet are grown."

In the palace of the King of Iberia stood gold and silver vessels filled with barley juice.

The Hebrew patriarchs were shepherds of animals on grasslands. Joseph, in his first dream, saw "sheaves of grain." Moses promised the Hebrews that "He (God) will put grass in your fields for your cattle." Nearly all of the religious sacrifices included a grass-eating animal or grain of the cereal grasses. The story of Ruth is built around barley and wheat. There are numerous other references to grasses in the Bible.

CIVILIZATION IN AFRICA

In Egypt, wheat and barley were cultivated by 4000 B. C. In the Egyptian "Book of the Dead," King Osiris states: "I am Osiris. I live as Grain. I grow as Grain. I am Barley." The Pharaoh of Joseph's time, in his first dream, saw seven fat cows grazing in the meadow

grass, and his second dream pertained to "seven ripe and seven thin ears of grain" (probably barley).

In other parts of Africa, civilization was based on another group of grasses, the sorghums. Barley and millet also were important articles of food.

CIVILIZATION IN EUROPE

In what is now Switzerland and northern Italy, the chief crops cultivated by the Lake-dwellers were barley, wheat and millet. Wheat was cultivated in Hungary during the Stone Age. The Macedonians, when invading Asia, became familiar with the cereal grasses grown there and introduced them into their own country as food-crops.

In Rome, the first known reaper was invented in connection with the harvest of grain. Polenta, a porridge made from barley, was fed to gladiators who were called *hordeari* from *hordeum*, the Latin name for barley. The word "cereal" is from the Latin "*cerealia*," which were grain festivals in honor of the goddess Ceres.

The Lithuanians, Germans, Celts, Gauls, Illyrians, Thracians (in modern Hungary) and Numantians (in modern Spain) ate millet, barley and wheat, and drank beverages made from these grains.

CIVILIZATION IN AMERICA

The physical, social and religious life of the Mayas, Aztecs, Incas, Guatemalans, Peruvians and other American peoples was based on maize or Indian corn.

The early settlers in America brought with them from Europe seed of rye, wheat, oats and barley, and planted these for crops as early as 1625.

OTHER ASPECTS OF CIVILIZATION

The calendar came into existence as a matter of necessity connected with cereal agriculture. Nomadic life required no calendar; the natural division of time into day and night was sufficient.

But the cultivation of the cereals, to be successful, required a calendar according to which planting and other agricultural operations could be performed at the time found by previous experience to be best. In the earliest Babylonian calendar, the names of eight of the twelve months of the year refer to grain. In the Egyptian calendar, certain of the names of the months also refer to cereals—"Sprouting of the Grain," "Making and Watering Barley," "Ripe Grain," and "Lady of the Granary."

The earliest problems in various branches of arithmetic concerned grasses—their agriculture, their conversion into flour and loaves of bread, and their distribution to the laborers. Some of the beginnings of geometry were likewise related to grasses—the measurement of the areas of grain fields and the consideration of various forms—cylinder, rectangle, or parallelopiped—as the most economical shape for granaries. What was probably the very beginning of astronomy was the institution of observing the moon as a basis for performing the steps in the cultivation of the cereal grasses at certain times. (Many people, even in civilized countries in this century, plant seeds of crops according to the moon.)

There were a few plants other than grasses which were cultivated before historic times, *e.g.*, the soybean, date-palm, hemp, flax, peach, apricot and grape-vine. In no case, however, was any civilization dependent upon any of these plants, whereas every known civilization has been made possible and necessary by the cultivation of one or another of the cereal grasses.

CHARACTERISTICS OF THE GRASSES

The grasses are apparently ideal pasture-plants because, instead of growing as other plants do, at the tips of the leaves which are eaten off by the grazing animal, grasses grow at the joints, the lowermost of which are generally

inaccessible to the animal's mouth and are therefore uninterrupted in their growth. This explains, too, the ability of lawn grasses to continue providing a turf in spite of frequent cutting.

As food for man, a cereal grass produces each year a large yield of edible, storable and transportable food, containing a great deal of nutriment for its volume. The grasses, in addition, grow in a greater variety of conditions of climate and of soil than do any other large plants. Grasses are the chief plants which possess all the characteristics in the right proportion for constituting man's basic food.

USES OF GRASSES

Food

Bread is still the "staff of life." Breadstuffs, furnishing the sole or chief food of most of mankind, are made from grasses.

As for meat, it is true almost literally that "all flesh is grass." Animals feeding on grasses furnish beef, mutton, pork and poultry, and such by-products as milk, cream, butter, cheese, oil, eggs, wool and leather.

Most of the world's supply of sugar is made from the grass, sugar-cane. Molasses is made from sugar-cane and sorghum. Beers and similar beverages are made by fermenting the seeds of grasses—maize, barley, rice, bamboo, millet and others.

Grasses, in the form generally consumed by man, are deficient in both minerals and vitamins and must be supplemented, if growth and health are desired, by fruits and vegetables.

Building Material and Land Reclamation

Where the bamboos grow, they constitute the material out of which houses, furniture and scores of other construction objects are built. Grasses are used in the tropics to build huts and tree-houses.

For the reclamation of useless or troublesome types of land, grasses are the leading plants. Beach grass is the pioneer for reclaiming sand-dunes in the temperate regions of the world. Cord ("Rice") grass (*Spartina spp.*) is the prime plant used to reclaim mud-flats and tidal estuaries. Both of these plants are used notably in North America and in Europe. For reclaiming alkali lands for agricultural utilization, several grasses are the best adapted plants known.

Grasses in the Landscape

Grass lawns render houses and other buildings attractive. Parks owe much of their beauty and probably all of their utility to grass. Golf courses and athletic fields are grass turfs. Some grasses are used as ornamental plants in gardens, e.g., bamboo, pampas grass, zebra grass, quaking grass and "gardener's garters."

Miscellaneous Uses

A small portion of the world's supply of paper comes from grasses. "Straw" hats are made from the stalks of various grasses. Whisk-brooms and sweeping-brooms are manufactured exclusively from a grass known as broom corn. The standard feed for birds is the seed of canary grass. Fishing-rods, and the vaulting poles used in Olympic games, are the stems of bamboo.

Corn stalks yield furfural, which is used as a solvent in resins and lacquers, and as a preservative in veterinary embalming material. Corn-starch is used in the stiffening and finishing of textiles, as a finisher and filler in the manufacture of writing-paper, as a stiffener in laundry work, and as a constituent of baking-powder, pies, puddings, soap, paints, adhesive substances and asbestos products.

The bamboos furnish cooking and other domestic utensils, musical instruments, hats, smoking-pipes, clothing and

literally hundreds of other every-day needs of millions of people living in the tropics.

The grasses cause more hay fever than probably any other group of plants. Although constituting one of the largest families of plants, the grasses contain hardly any poisonous representatives, only the stunted or second growth of the sorghums being poisonous to animals.

EXTENT OF GRASSLANDS

Grassland is the prime form of vegetation on the Great Plains and prairies of North America, on the savannahs and pampas of South America, on the veldt covering immense areas of Africa, on the enormous steppes of Russia, Siberia, China and Manchuria, on the grasslands of Australia and New Zealand, and on the lesser grassland areas distributed elsewhere on the earth's surface.

Much land is covered with cultivated grasses. For example, Indian corn is grown in the United States on over 100,000,000 acres, a greater area than that of California. Similarly, rice, wheat, barley, millet, oats, sorghum, sugar-cane, bamboos and pasture grasses cover very large areas of the earth's surface. In all probability, grasses occupy a greater portion of the dry surface of the earth than all artificial and other natural formations combined.

Grasses grow in the Arctic regions, where they constitute approximately one fourth of all the flowering plants and are more numerous than any other single family of large plants. Grasses grow, by contrast, in the hottest portions of the tropics. They are found at sea-level and on the highest mountains, in the open and in shade, on plains and on hillsides, in water and in sand, in forests and in deserts, on alkali soils and on acidic soils. In fact, grasses are found, often to a dominant extent, in any environmental condition in which plants can grow.

The family of grasses contains a larger

number of individuals than all other families of large plants combined.

VALUE OF GRASSES

The most valuable crops in the world are grasses—the cereals, sugar-cane, bamboo and hay. Statistics do not include the grass on ranges and pastures which is consumed directly by animals without going into commerce, where its value can be recorded. In the United States, maize, hay, wheat, barley, oats and rye have an annual worth of about six billion dollars.

SUMMARY

The geologic Age of Mammals was, in large measure, made possible by the formation of grasslands.

The almost exclusive food-supply of primitive man was the meat of the animals which lived upon grass or which

preyed upon grass-eating animals. Early man was a nomad, following these animals from one grassland to another.

Every known civilization had its beginning in the cultivation of one or another of the cereal grasses.

At present, grasses furnish all the breadstuffs and most of the meat and sugar consumed by man. They also supply housing material for millions of people in the tropics.

Grasses are adapted for growth in a greater diversity of environmental condition than are any other large plants. Probably the greatest portion of the earth's dry-land surface is covered by grasses.

In general, human existence and civilization have thus far been very closely related to the natural and agricultural importance of grasses.

COOKING CAMAS AND BITTER ROOT

By Professor HARRY TURNEY-HIGH

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Now that the old way of life is passing so quickly in western Montana, the local anthropology staff is frequently asked about the ways the Interior Salish tribe of Flatheads (improperly so-called) prepared their staple vegetable foods, the root of the camas (*Quamashia quamash*), and the bitter root (*Lewisia rediviva*). The process is becoming increasingly difficult to observe. For with every recurring bitter root season, we notice fewer and fewer tipis pitched on the flats south of the university. The culture of the Salish is passing, along with their grand old men, whose descendants are not content to be Men Without Machines. The rapid diffusion of the easy Woolworth-pot-and-pan complex has perhaps made the following cooking method impossible ever to see again. I am deeply indebted to my friend, Mr. John Frohlicher, who has lived longer

among the Salish and has witnessed the preparation of the feast untainted by white culture oftener than I have, for this description.

The roots of the two foregoing plants have been, and to a considerable extent, still are, the primary cause of the spring-time tribal movement of these semi-nomadic people from their winter game areas around Flathead Lake to the regions where the plants are plentiful. The camas root is found in appreciable quantities north of Flathead Lake on the old lake bed, and southwest of the lake on its former channel to the Columbia. The bitter root is found in great quantities on the flats on which the city of Missoula and the campus of the State University of Montana now stand, as well as in the Bitter Root Valley, which extends many miles south of Missoula.

It must be remembered that these peo-

ple of the northern part of the Plateau culture area are tribes without pottery or even basketry, unless they could trade with their cousins, the Nez Percés, for the latter. The ancient method of preparing the camas bulb is a variant of the pit-baking process. A pit about 10 feet long and from 2 to 3 feet wide is dug, and a fire of intense heat is therein kindled. The Salish prefer to use cottonwood limbs and bark for this fire, since they burn longer than the conifers so plentiful in this region.

When the wood is reduced to glowing coals, red willow sticks with the sap still in them are crisscrossed over the fire-bed in the form of a gridiron. Over this is laid a blanket of green grass, ordinarily the abundant bunch-grass, some 2 to 3 inches thick. Upon this, in turn, is placed a layer of moist earth. The final layer of this blanket consists of another coating of green grass. Then the camas roots are dumped into the pit. The mass is covered with more grass and a thick layer of earth. Another fire is now kindled on top of the heap, and kept alive from twelve to eighteen hours, when it is raked away and the oven opened for the prepared food.

The camas roots are then found cooked to the consistency of boiled beets. They are sometimes eaten raw. But in that state they have an unpleasant bitterness which is lost in the cooking. Actually, the camas bulbs have very little nutritive value, and, like our cooked onions, should be considered a condiment.

The bitter root is considered edible only when the plant is in flower. So at the time when this charming blossom is dotting the valleys, the tribesmen gather at the sites where the herb is plentiful. The women and children are then busily engaged in digging the roots while the gentlemen amuse themselves. The older Indians assert that the common way of cooking bitter root in the old days was

similar to the hot pit method described for the camas. However, the root was often dried for winter use and stored in parfleches. In this instance, they were usually ground into a flour, a paste made and baked into cakes about the size of a small pancake. Modern Salish have discovered that the cakes keep as well as the unprepared dried roots, and are very apt to save labor by cooking their winter's supply into cakes immediately after the harvest. As it is said of olives, the bitter flavor of these cakes does not often appeal to the novice, but a taste for them may be acquired.

As with modern military empires, the ecology of the food plants and animals of the Northwest had profound effects upon the relations of the Flatheads with their neighbors. The camas and bitter root are not found on the semi-arid plains, and the Plains type Indians, lacking adequate vegetable food, sought treaties with the Salish monopolists, enabling them to enter the valleys and gather the plants. In exchange for this privilege, the Plains people were to permit the Salish to enter the eastern grass lands in search of the bison. However, these treaties were rarely kept. The militant Piegan Blackfeet often scorned to ask permission of the Salish, whom they despised, to enter the valleys to gather roots. On the other hand, the Salish, seemingly bent on losing their hair, claimed an inalienable, ancient right to enter the Plains whenever they saw fit. These treaty rights and the violation of them made this country a shambles for centuries. Whatever else may be charged against the white man in western Montana, and his record is no more honorable than need be, his presence and that of his army undoubtedly kept the fierce Blackfeet from completing the process of exterminating the numerically inconsequential "gentle Salish" whom Lewis and Clark loved.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

HEAD HUNTERS OF THE AMAZON

By MATTHEW W. STIRLING

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THE curious custom of preserving human heads taken in warfare has been practiced by primitive peoples in several parts of the world, but in no region is this activity pursued more vigorously nor in so specialized a fashion as by the Jivaro Indians of South America, who prepared their captured heads by shrinking them to the size of a small orange while preserving perfectly the features of the victim. Having recently lived for several months among these Indians, I will try to describe to you their country and a few of their customs.

In eastern Ecuador, where the Andes fall away in range after range of jungle-clad mountains, there is a great basin, drained by the Upper Maranon and Santiago rivers. Entrance to it from the west is barred by the snowy peaks of the high Andes, while from the east a formidable obstacle to travel is presented by the famous Pongo Manseriche, the great gorge through which the combined waters of the Maranon and the Santiago burst through their final mountain barrier into the vast Amazonian plain. In this region of torrential streams and rugged mountains live upward of thirty tribes of the so-called Jivaro Indians. Isolated in this remote corner of the world, they have maintained their primitive customs almost unchanged by contact with the white man.

Warfare is the very center of existence to the Jivaro, and his entire cultural pattern is woven around it. War is conducted on the principle of blood

revenge, the practice of which is a sacred duty which no Jivaro would dare refuse. Fathers begin instructing their small sons at the age of five or six years, lecturing them each morning when they first awaken on the necessity of taking blood revenge for his relatives who have been killed in the past. Their names are recited to him, as are also the names of the families and individuals who have done the killing. This instruction is rehearsed to the boy daily until he is about twelve years of age and thoroughly impressed with his duty. Small boys accompany their fathers on war expeditions before they are capable of bearing arms in order that they may become accustomed to the realism of killing and learn the tactics of warfare from direct observation. So actively is head hunting practiced that the women, who are generally not killed in the raids, greatly outnumber the men, thus making polygamy a social necessity. Three or four wives to a man are common and I know one Jivaro, much respected for his courage, who has twelve.

A Jivaro community consists of a single house, in which live not more than thirty or forty individuals, generally comprising a group of related families. This community house is strongly built, usually on the top of a hill or the edge of a bank, with an eye to its defensibility. The walls of the house are constructed of pickets of palm wood or bamboo lashed firmly together, and the high roof is covered with palm thatch. One half of the house is the exclusive

domain of the women, the other half is occupied by the men. Each half has its own door, made by setting logs vertically in a slot at the entrance.

Imagining ourselves in the house, we see lashed against the high center posts the long blow guns with their bamboo quivers of poisoned darts, which the Jivaros use as their principal hunting weapon. In the same position, standing upright, are the long lances of hard black palm wood which are the chief weapons of their war expeditions. Hanging from the center posts or lying on platforms over their beds of split bamboo are the big painted circular wooden shields used in warfare. The Jivaros do not have the bow and arrows, but many of the men use cheap muzzle loading shotguns, obtained usually by trading human heads.

Conspicuous in the center of the women's half of the house are a number of huge red earthenware jars filled with a mildly intoxicating drink called mesato. This drink, which is the central feature of all feasts and ceremonies, is consumed in great quantities by the Indians, to whom it is both food and drink. The women who make it prepare it by chewing manioc root and spitting the resulting mixture of starch and saliva into the jars, where it ferments. It is necessary for all visitors to a Jivaro house to drain a bowl of this drink which is always offered as a gesture of hospitality.

There are many causes of war, but by far the most common is the killing, or supposed killing, of some member of a group by some one in another group. Since it is a point of honor always to be one ahead of the other fellow, it is easy to see why the cycle of killings becomes almost endless. To further complicate matters, very few deaths are attributed to natural causes. If a man dies of illness, that illness is believed to have been sent into him by the medicine

man of some enemy group. If a man is drowned in the river, it is because some enemy has caused the great river serpent to upset his canoe. The medicine man of his own group then takes certain drugs, under the influence of which he learns the identity of the culprit. This accomplished, a feast is held, much mesato is drunk and war is declared against the household of the supposed killer.

Custom demands that a warning be sent to the house which is to be attacked. As soon as this is received, the group to be attacked prepares pitfalls containing sharp stakes around the house and place set guns and traps on all the trails approaching. The attacking party divest themselves of all clothing and stain their faces and bodies black with a vegetable dye. Each man carefully prepares his hair and puts on his finest head ornaments. This preparation, they explain, is so that in case the attacker should have his own head taken he would have nothing about which to be embarrassed. A group of women accompany the war party in order to prepare their food.

The attack invariably takes place at dawn. Although the attacking party is by no means always victorious, we will assume for purposes of illustration a successful raid. The defending party, knowing of the impending attack, have tied dogs at various strategic points around the garden clearing which surrounds the house. Their barking gives warning of the arrival of the raiding force in the night. While awaiting the first sign of dawn, the two parties endeavor to terrify each other by loud shouting and the exchange of threats and insults. During this time the great wooden telegraph drum in the house is being pounded incessantly, while both groups dance wild dances and sing war-like songs. When the first traces of dawn appear, the attacking party, shouting at the tops of their voices, rush the

house and attempt to force an entrance. In the meantime the defenders fire upon them from between the wall pickets. When a breach has been made, the attackers pour in, fighting hand to hand with lances. The interior of the house becomes in the half light a scene of greatest confusion.

The shouting of the warriors, the screams of the women, the crying of children and the barking of the dogs mingle to produce an effect difficult to describe. The warriors, working in pairs, try to outmaneuver one another so as to get in their lance thrusts from behind. When all the men have been killed or have escaped, the small children and the old women are lanced and all the marriageable women are taken captive. Each fighter who has killed a man severs the head of his victim with his lance and wraps it carefully in a basket. The dogs are all killed, the plants in the gardens uprooted and destroyed, and the house itself is burned. A brief meeting is then held in which the captive women are apportioned as wives to various members of the victorious party, and any disagreements are settled as to who is entitled to the heads which have been taken. It frequently happens that some of the victims are relatives of members of the attacking party. In this case, these heads are not taken.

At a camp by a river the returning party stops to prepare the heads which they have taken. The heads are skinned much as one would peel off the skin of a rabbit. The skin is first reduced to one third its original size by a boiling process and further reduced and dried by applying hot rocks and hot sand. Finally the head is smoked, which blackens it and enables it to be polished as one would shine a shoe. The top of the head is then pierced and a cord attached in the form of a loop. The entire operation requires great skill. Young men

preparing their first heads are instructed by experienced warriors, who sit by their side during the entire process.

When the party returns to its house, each victor wears the head which he has taken around his neck, suspended by the loop. Upon entering the house the heads are removed and hung upon lances thrust in the floor. The warriors are painted by the women and an elaborate ceremony follows, during which both men and women dance around the heads, singing and casting insults. While the dance is partly a dance of triumph, its purpose primarily is to bottle up the spirit of the victim in the shrunken head so that it will be unable to escape and harm the killer. For the same reason, following the ceremony, each victor must rigidly observe a number of taboos for a period of six months. There are a number of Jivaro men living today who have taken as many as forty or fifty heads in their time. This curious custom, which seems so revolting to us, is not the result of any unusual strain of cruelty in these Indians. In other respects they are as kindly and as capable of tender sentiments as any civilized group. Their fighting follows a recognized set of rules, and killings are never perpetrated without what they consider a just cause.

In most other respects their morality might well be taken as a worthy model for civilized man. The custom of head hunting evidently had a long period of growth which in time fixed it so firmly into the cultural anatomy of the Jivaros that they now can not imagine existence without it. Before we criticize them too severely, we might first examine our own social structure. Some of our undesirable customs are a bit more subtle than that of head hunting; and if we do not have any one custom as bad, at any rate we have more of them.

"CONCERNING DRAGONS"

By CHARLES W. GILMORE

CURATOR OF FOSSIL REPTILES, U. S. NATIONAL MUSEUM

MANY millions of years ago this world was inhabited by a race of strange reptiles upon which science has bestowed the name of dinosaurs. Although all these animals disappeared millions of years before there were any people in the world, from a study of their fossilized remains it has been possible to learn how many of them looked when alive, what they ate, where they made their homes and in some cases how they died.

The name dinosaur is usually associated with an animal of great bulk, having a long tail and neck, but in addition to this popular conception there are many other kinds. While it is true that some were the biggest land animals this world has ever known, there were also living at the same time some that were very small. They differed greatly in shape, structure and habits. Some walked on all four feet; others, with small weak fore limbs, walked upon strongly developed hind legs like ostriches. Some were provided with long sharp claws; others had flattened hoof-like nails. There were dinosaurs with small heads and others with very large heads. Some were big and cumbersome, others were small, light and graceful and so much resembled birds in their structure that only the skilled anatomist is able to distinguish their fossil remains. Some of large size were clad in coats of bony armor, giving them a bristling appearance. Some were flesh-eaters and others fed only upon plants.

In size the largest of the dinosaurs exceeded one hundred feet in length. An actual skeleton of one of these huge reptiles in the U. S. National Museum in Washington, known as *Diplodocus*, measures over seventy feet in length and stands over twelve feet high at the hips.

Taking *Diplodocus* as a typical example of the largest of these animals, this dinosaur may be said to consist principally of tail and neck with a short body between, that is, supported by four stout elephantine-like legs, its proportions being: tail forty-eight feet, body twelve feet and neck twenty feet. At the end of the neck is a small head about the size of that of a horse. It is estimated that in life *Diplodocus* weighed twelve or more tons. The wonder of it all is how did an animal of such great bulk manage with such a small mouth to secure food enough to sustain itself. Certainly eating must have occupied all its waking hours.

With this brief sketch of the largest of the dinosaurs, let us consider for a moment some of the other kinds. The smallest dinosaur known is but a little larger than a chicken, and is remarkably bird-like in its structure. It walked around entirely upon its hind legs, the body being balanced by a long tail. Then we have the hadrosaurs or duck-billed dinosaurs, also walking on two feet, that were plant-eaters, and of many different kinds, large and small, some with high bony crests on the top of the head, suggesting the comb of a rooster. One of the striking peculiarities of these animals is the development of a remarkable battery of teeth; oftentimes there are as many as 2,000 teeth in the jaws of a single individual. These teeth are arranged in longitudinal and vertical rows, and when a tooth is worn out or lost through accident, the next tooth below moves up to take its place, thus insuring a full dental series throughout the life of the individual, which in this respect gives these animals a decided advantage over ourselves.

Usually only the hard parts, bones and teeth of the skeleton are fossilized, but under exceptional conditions impressions of the external covering are occasionally found. Such skin impressions have been found with several specimens of the duck-bills, so that now we have a very definite idea of their external appearance. It is known that they were covered with a scaled skin, made up of small horny scales which are arranged in beautiful mosaic patterns. This skin pattern is also known to differ in the different kinds of dinosaurs.

The outstanding discovery of recent times concerning the habits of the dinosaurs was the discovery in Mongolia of fossilized eggs. It has been long surmised that these reptiles reproduced their kinds through the medium of eggs, but this was the first positive proof of that fact. The largest of these eggs were about the size of those of the ostrich, cylindrical in shape, a form characteristic of many living reptiles. We are told that as many as nine were found together in one place. One of these eggs is said to contain an embryo.

There lived at the same time with the dinosaurs previously mentioned, all of which were plant eaters, both large and small flesh-eating or carnivorous dinosaurs. The giant among these is known as *Tyrannosaurus*, the tyrant saurian. It reached a length of forty-seven feet, and in a standing position, which was entirely on the hind legs, was eighteen or twenty feet high. The head was over four feet long, and the long powerful jaws were provided with sharply pointed teeth from three to six inches in length. To this powerful armament was added the great sharp claws of the hind feet and probably those of the fore feet, curved like those of the eagles, but much longer, being six to eight inches long. This animal was one of the largest and probably the most ferocious beast that ever inhabited this old world of ours.

There were others of intermediate size, like *Triceratops*, the dinosaur with the three-horned face, for that is what the name implies. These horns grew one over each eye and a smaller one on the nose. The large horns above the eye sometimes are more than a yard in length and are sharply pointed. Skulls of these animals reach a length of over eight feet, due to the development of a bony frill that extends backward over the neck like a fireman's helmet. This is the largest-headed land animal ever known, the skull being about one third the total length of the entire animal. Although the horned dinosaurs were plant feeders, they often engaged in combat, as is shown by the healed wounds that are found in many a skull, broken horns and in fractured and healed jaws and other bones of the skeleton.

Another group with striking peculiarities are the armored dinosaurs, so called because of the development of an armor composed of bony skin plates. The most peculiar member of this group is one whose remains are found near the close of the age of reptiles and has been popularly designated the "Super-Dreadnaught of the Animal World." Picture in your mind a short, squatly animal, perhaps twelve feet in length, with a body nearly five feet in width, short massive legs, heavy tail and a small flat-topped triangular skull. The back is covered with innumerable little nodules of bone that were embedded in the skin, and at intervals were set, in more or less regular fashion, large flat plates and spines. On the end of the tail there was a great thickened triangular mass of bone appropriately called the "tail-club." The head was turtle-like and was provided with a broad rounded horny beak used to nip off the vegetation. Even the eyes were protected by a bony cup-shaped shutter that could be closed over the eye when the animal

so desired. Thus protected by his covering of bony armor, this animal was in reality an animated fortress, and need have no fear of its enemies. There were other kinds of armored dinosaurs, but none quite so peculiar as the one just briefly sketched.

It is the general impression that extinct animals, especially the dinosaurs, have a corner on all that is unusual in size and grotesqueness of form. While in length they probably were the longest animals ever known, in bulk none of them exceeded the whales of the present day. In manner of appearance it must be borne in mind that many of the striking peculiarities of the dinosaurs are enhanced by their great size, for, were some of the living reptiles, especially the lizards, enlarged to the same proportions, they would be equally bizarre in appearance.

That in ancient days the regions where the dinosaurs lived enjoyed a warmer climate than that of to-day is abundantly indicated by the palms, cycads, figs and other tropical plants preserved as fossils with the animal remains. The dinosaurs were practically world-wide in their distribution, their remains having been found on all continents, but nowhere are they more abundant or in a better state of preservation than in that strip of country running north and south along the eastern flank of the Rocky Mountain range. Here is where the best preserved specimens have been found, but it may be of interest to know that these animals also lived along the Atlantic seaboard.

Another query that often arises is: How did the skeletons become entombed where they are found to-day? There are many ways in which this may happen, but a typical example will suffice. Ani-

mals dying in swamps may mire down into the water and muck and thus be immediately covered; or in the event of death having occurred along a stream the carcass, buoyed up by generated gases, might be carried down stream to be lodged in shallow water on a sand bar, where, as decomposition progressed, the bones of the skeleton would settle into the sand, there to be covered by shifting sand washed over them by the action of the current. This sand in many years following, accompanied by subsidence of the whole area, was covered deeper and deeper by other sediments, until finally many hundreds or even thousands of feet of overlying materials had accumulated. The great pressure brought about by the accumulated weight of the overlying strata consolidated the loose sand into hard sandstone, in which the fossils are commonly found. While all this has been going on the bones have also undergone a change, in that the organic matter of the bone has been replaced by mineral matter and the skeleton has become fully petrified. This has been brought about by the infiltration of water charged with mineral in solution, such as calcite, silica or iron, and as the organic matter is leached out the mineral is deposited in its place, until finally the fossil bone becomes as solid and heavy as rock itself.

The uncovering again of the fossils so deeply hidden by overlying sediments occurs only in favorable localities. It may be brought about by the erosion or carrying away of the superimposed strata, or by the more rapid cutting down through of a deep gorge of valley by streams and thus again uncovering the skeletons and making it possible for the collector of fossils to come into his own.

PERFUMES AND PROGRESS IN SCIENCE

By Dr. MARSTON T. BOGERT

PROFESSOR OF ORGANIC CHEMISTRY, COLUMBIA UNIVERSITY

I WONDER if my radio audience are familiar with the facts that the use of perfumes and perfumed unguents is as old as the human race; that some of the vases found in the tomb of the Pharaoh Tut-anhk-Amen were used to hold such materials; and that there used to be a law on the English statute books which made the use of perfumes subject to the same punishment as sorcery?

How has it come about that, of our five special senses of sight, hearing, taste, touch and smell, the cultivation of the last named has been not only neglected quite generally, but has also been scorned and more or less despised by most of the male sex as a frivolous and effeminate pursuit? Yet this sense was well developed and efficient in other animals long before the human animal, as we now know him, was evolved. So that from the dawn of his history man has distinguished between odors and derived enjoyment from those which appealed to him.

As an analytical instrument, the nose is far more delicate than the spectroscope, and the trace of an odor which it can clearly detect is unbelievably minute. No other sense is so marvelously acute as that of smell, so widely and extensively connected with other brain centers, or so potent in awakening our memories and our emotions. Kipling was physiologically and psychologically correct when he wrote that "Smells are surer than sounds or sights, to make the heartstrings crack." A breath of perfume brings instantly before our vision past scenes with all their pain or pleasure. Shrewd business men have already awakened to the powerful sales aid to be obtained from perfumes, and at last understand that an appeal to the nose is often more potent than one to the eye.

Why is it that the art of the perfumer is not taken so seriously as that of the musician, the painter or the sculptor? We teach our young people to distinguish musical sounds and color effects, harmony in music and in pictorial art, but the vast possibilities of artistic enjoyment provided in our wonderful olfactory endowment they are left to learn in the slow, unsatisfactory and casual school of practical experience, with the result that even our language lacks specific descriptive adjectives by which variations in odor can be accurately characterized in the same way that we can describe differences in color and in shade. There are masterpieces in perfumery, as in other arts, but those qualified to understand and appreciate them are few indeed.

Probably the reason why the sense of smell was extensively developed in animals sooner than the other special senses was that most wild animals depend more upon scent than they do upon sight to guard them against danger. In many animals this development far transcends what we find in man. The ability of dogs to follow unerringly a scent which can not be detected by the human nose is a familiar example.

Many insects are strongly odoriferous, the odors emitted being usually disagreeable, although "the males of many butterflies give off a pleasant fragrance similar to and rivaling in attractiveness that of the scented flowers." Insects also possess a remarkably well-developed sense of smell, and it seems quite certain that most human pests and parasites, like gnats, mosquitoes, bedbugs, etc., locate their prey mainly by odor. Some of the most striking investigations are those which have been carried out with ants, insects which exhibit also surpass-

ing powers of odor-association and odor-discrimination, enabling them not only to distinguish the smells characteristic of species, caste, sex and individual, as well as the adventitious odors of the nest or surroundings, but also even progressive odors due to the changing physiological condition of the individual with advancing age, a refinement which in the case of humans might often save us many complications and embarrassments.

This predilection of different forms of life for special odors has been used with considerable success to attract to their destruction not only animal pests, but insects as well. In this way, the geranium perfume has been used as a lure for the dreaded Japanese beetle, and an odorous constituent of the cotton plant for the boll weevil, the object being to induce these insects to collect in vast numbers, where they can be killed *en masse*.

The two major classes of perfume raw materials are the natural and the synthetic. Both are required for the production of fine modern toilet perfumes. They are the pigments with which the perfumer paints his picture.

The natural perfumes are either animal or vegetable. Of the former, but four are of any commercial importance, and these are the ambergris from the intestinal tract of the sperm whale; the musk from the preputial sac, or "pod," of the diminutive male musk deer, a graceful little creature, the sole source of genuine musk, now threatened with extinction, unless the recent brilliant efforts of the organic chemist in the preparation of new synthetic musks prove successful; the civet from the anal gland of the civet cat; and the castor, which consists of the dried preputial follicles and their secretion from both male and female beaver. The vast majority of natural perfumes, of course, come from the vegetable kingdom, where they occur as the volatile or essential oils, or as the

gum resins and balsams. The flowers are not always the source of these odorous plant constituents. They may be in the wood, as in sandal and cedar; the bark, as in cassia and cinnamon; the leaves, as in patchouli, bay and thyme; the fruit, as lemon and bergamot; the seeds, as almond and caraway; or the roots, as orris and sassafras. From the appropriate part of the plant, the odorous constituents are obtained sometimes by direct pressure, sometimes by distillation with steam or extraction with suitable solvents; in other cases, the aroma exhaled by the flowers is absorbed by thin layers of fat or oil, from which material the perfume is subsequently extracted by alcohol. Do you know that it takes approximately two tons of roses to produce one pound of "attar" of roses?

The synthetics, on the other hand, are manufactured in man's laboratory instead of in that of the plant and, as in the case of drugs and dyestuffs, the organic chemist is rapidly outdistancing nature in this fascinating field, the sceptics in my audience to the contrary notwithstanding, and has already made available hosts of odorous products which nature does not provide. His intensive investigations necessary to achieve this result have meant striking progress in the science of chemistry. He has even discovered a synthetic geranium perfume which is so stable to heat and so cheap that it has been used successfully in a power-plant boiler, to generate steam. This geranium-scented boiler room has been in actual operation, although still in the experimental stage.

How impossible it is to foresee what may be the outcome of scientific research, or whither it may lead, is admirably illustrated by an investigation which began some forty years ago, the purpose of which was to discover the chemical to which the violet owed its delicious fragrance. The knowledge thus gained was used by the chemist to produce in his

laboratory some very fine violet perfumes, which have been used ever since in violet toilet preparations. Other chemists then investigated the perfume of orange blossoms and of some acacia flowers, and soon found out that the building blocks which nature had used in constructing these beautiful products were exactly the same as she used in making rubber, and differed only in their architectural arrangement.

It was these researches in the perfume field which have enabled us to learn so much about the chemical character of chlorophyll, of many other plant coloring matters, of some constituents of fish-liver oils of particular interest to the biologists and biochemists, and have led finally to a probable formula for vitamin A, that compound which has such a remarkable effect upon human growth and longevity. It certainly never entered the minds of these early workers in the perfume field that in unraveling the constitution of these perfumes they would discover the key which would unlock many other hitherto closed doors.

Who could have guessed that the delicious perfumes of the violet, of acacia flowers and of orange blossoms had anything whatsoever in common with the liver oils of the shark, flounder and mackerel, with the green (chlorophyll) and yellow (xanthophyll) coloring matters of leaves, of the red pigments of the tomato, of the red pepper, or of the Chinese lantern plant, the yellow or orange pigments of carrots, dandelions, sunflowers and yellow pansies and the brown coloring matter of some seaweeds; or that the molecular configuration responsible for orris and violet perfumes likewise formed an integral part of the molecule of the carrot pigment and of vitamin A?

Many human ailments are accompanied by the genesis of odors resulting from putrefactive or other destructive processes. These odors are specific chemical compounds, yet the medical profession seem strangely indifferent or sceptical concerning their value in the diagnosis of a disease, although it is not at all improbable that every pathogenic organism is characterized by the production of only certain definite odors. Those who have been so unfortunate as to have had surgical operations often acquire such a strong antipathy to the odor of the general anesthetic used as to render any subsequent operation doubly dreaded. Might not the incorporation of a suitable perfume in anesthetics and hypnotics diminish somewhat this feeling and enable the sufferer to fall asleep with the fragrance of some favorite aroma still in his nostrils? It might even influence pleasurable his dreams in that "twilight sleep" between consciousness and unconsciousness.

The perception of an odor is a physiological process, and further study of the connection between chemical constitution and odor will throw increasing light upon the dependence of other physiological effects as well as upon chemical constitution. This will show us how to cope more successfully with disease and to bring greater relief to human suffering. It is not by any manner of means inconceivable that the final solution of that master problem of chemistry, as to exactly what is the nature of those complex changes which determine the mysterious cycle we call life, may some day burst upon us as the direct outcome of the researches of the organic chemist in this "frivolous and effeminate" field of perfumes.

PHOTOGRAPHS OF THE WHALE SHARK, THE GREATEST OF THE SHARKS

By Dr. E. W. GUDGER

BIBLIOGRAPHER AND ASSOCIATE IN ICHTHYOLOGY, AMERICAN MUSEUM OF NATURAL HISTORY, NEW YORK CITY

SHARKS are large marine fishes without any bony framework. Having only a cartilaginous backbone, very rudimentary cartilaginous pectoral and pelvic arches and no ribs, they are literally "loose-jointed." When brought out on land their bodies collapse and flatten down so that one can not get a true idea of their form, shape and proportions. This is particularly true of the whale shark, the largest, bulkiest and probably the most collapsible of all the sharks.

However, despite these things, photographs of the whale shark are especially desirable, since they will at any rate give some idea of the size and shape of the body, of the sizes and posi-

tions of the fins, and of the size and position of the vertical yellow bars and of the rows of large yellow spots between these. Having in my possession copies of all the photographs known to have been taken of the fish itself (excluding mounted skins and models) I have thought it well to bring these together for the instruction and use of those interested. Reproductions of all drawings, models and mounted skins may be found in a recent article¹ by me.

¹ E. W. Gudger, "The Fourth Florida Whale Shark, *Rhincodon typus*, and the American Museum Model Based on It," *Bulletin American Museum of Natural History*, 65: 613-637, 10 pls., 4 text-figs., 1931.



FIG. 1. THE SECOND FLORIDA WHALE SHARK—1912
DRAWN OUT OF WATER ON THE MARINE RAILWAY AT MIAMI.

—After Gudger, 1915



—After Gudger and Hoffmann, 1927
FIG. 2. NINE MEN ON A WHALE SHARK'S BACK
THE SPECIMEN TAKEN AT JAIMANITAS, CUBA, 1927.



—After Gudger and Hoffmann, 1927
FIG. 3. THE CAVERNOUS MOUTH OF THE JAIMANITAS SHARK
HELD OPEN BY THE HARPOON WITH WHICH IT WAS SECURED. NOTE HOW FLATTENED OUT THE
FISH IS.



After Gudger and Hoffmann, 1930

FIG. 4. THE WHALE SHARK ON THE SHORE AT COJIMAR BAY, CUBA
THIS SHOWS WELL THE REMARKABLE SPOTTING OF THIS GREAT FISH.

It seems well in this short note to restrict the figures to reproductions of photographs, showing the shark out of water and hence portraying approximately the whole fish. First, published figures will be given, and then several which have never before been reproduced.

The first of the former is taken from my paper on the "Natural History of the Whale Shark,"² published in 1915. This (Fig. 1 herein) is of the 38-foot specimen captured near Knight's Key, Florida, in May, 1912. It is here shown drawn up on the marine railway at Miami. As will be seen, it has collapsed and, since the "cradle" on which it rests had no flooring of planks, it is badly out of shape. However, one gets an idea of its enormous size, of its remarkable coloration, of the cavernous mouth with the tooth-bands showing in-

distinctly, of the small eye and of the large gill-slits.

In November, 1927, a 31-foot whale shark was captured at Jaimanitas, a fishing village about five miles west of the mouth of Havana Harbor. In an article by Dr. W. H. Hoffmann, of Havana, and myself,³ we reproduced three photographs of this great fish on the beach. Fig. 2 herein shows this great fish drawn partly on shore with nine men perched on its broad back. The collapsing when brought ashore is here shown plainly. Fig. 3 herein (Fig. 3 of our article) gives a good idea of the great shark. Note the prodigious mouth (held open by the harpoon with which it was secured), the great spread of the pectoral fins, the high-standing dorsal fin, the great length of the fish, and the upper half of the tail, which is nearly as high as a man is tall.

² *Zoologica: Sci. Contribs. New York Zool. Soc.*, Vol. 1, No. 19, p. 354, fig. 122.

³ *American Museum Novitates*, 1928, no. 318, 3 figs.

Some two and a half years after the capture of the Havana whale shark just figured, another was captured at Cojimar Bay, east of Havana Harbor, in March, 1930. Dr. Hoffmann and I published a note on its occurrence (without any illustration) in *Science* for June 20 of that year, and in the January issue of SCIENTIFIC MONTHLY for 1931 we published the beautiful photograph reproduced herein as Fig. 4. This well portrays the great size and remarkable spotting of this 34-foot specimen. The two harpoons with which it was struck are shown, as also the wire rope with which it was finally secured. The view of the head is marred by the shadow cast by one of the bystanders.

In this connection it may be said that Dr. Hoffmann and I have reports, which we think credible, that other whale sharks have been seen by fishermen in the Havana region. It does not seem too much to expect further ac-

counts with photographs of this great shark in this immediate vicinity.

These figures comprise all the published photographs showing the whole fish. Now follow four previously unpublished ones.

The first of these is a re-photograph of an old dilapidated picture made of a whale shark taken at Bacolod, Philippine Islands, in 1910. This (Fig. 5 herein) was kindly sent me by Dr. A. W. Herre of Stanford University. It was obtained while he was head of the ichthyological work of the Philippine Bureau of Science. No data are available as to size, but it was apparently between 20 and 25 feet long. It may be added that the whale shark is well known in the Philippine Islands—there are several accounts in the literature and many as yet unpublished.

The whale shark has been reported a number of times in the seas around Java, but unfortunately only one photo-

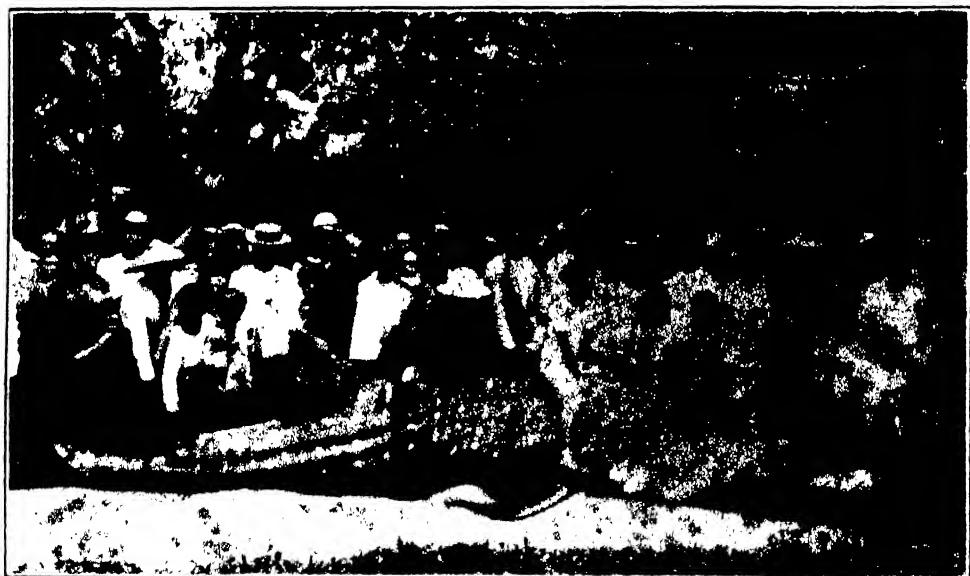


FIG. 5. WHALE SHARK TAKEN AT BACOLOD, PHILIPPINE ISLANDS, IN 1910
NOTE THE KEELS AND CHAMFERINGS RUNNING FROM THE SHOULDER REGION BACK TOWARDS THE
TAIL AND ALSO THE BOY IN THE FISH'S MOUTH.

Photograph by courtesy of Dr. A. W. Herre



—Photograph by courtesy of Dr. P. N. Von Kampen
FIG. 6. A WHALE SHARK SUSPENDED ABOVE THE HARBOR OF
SOERABAYA, JAVA

NOTE THE ENORMOUS GILL-SLITS, THE HINDMOST BEING THE SMALLEST.

graph has, so far as I know, ever been made. This is reproduced as my next figure, No. 6. It is a photograph of a whale shark suspended above the water of the harbor of Soerabaya, Java. This was kindly loaned me by Dr. P. N. Van Kampen of Leyden, Holland. He purchased the photograph in Java and knows nothing of the specimen, beyond the fact that it was said to have been

taken in the Straits of Madeira between Java and the island of Madeira. The fish is apparently about 18 or 20 feet long. It is of course very much distorted by the way it is suspended, but at least it gives a fine idea of the great size of the gill-slits. The shape of the pectoral fin is also well shown.

Next comes a photograph, which has recently been sent to me by Mr. Wallace



- Photograph by courtesy of Mr. Wallace Adams

FIG. 7. PHOTOGRAPH OF A SECOND PHILIPPINE RHINEODON
A 21-FOOT SPECIMEN TAKEN IN A FISH TRAP AT BARRIO APLAYA, BAUAN, BATANGAS, LUZON,
MARCH, 1932.

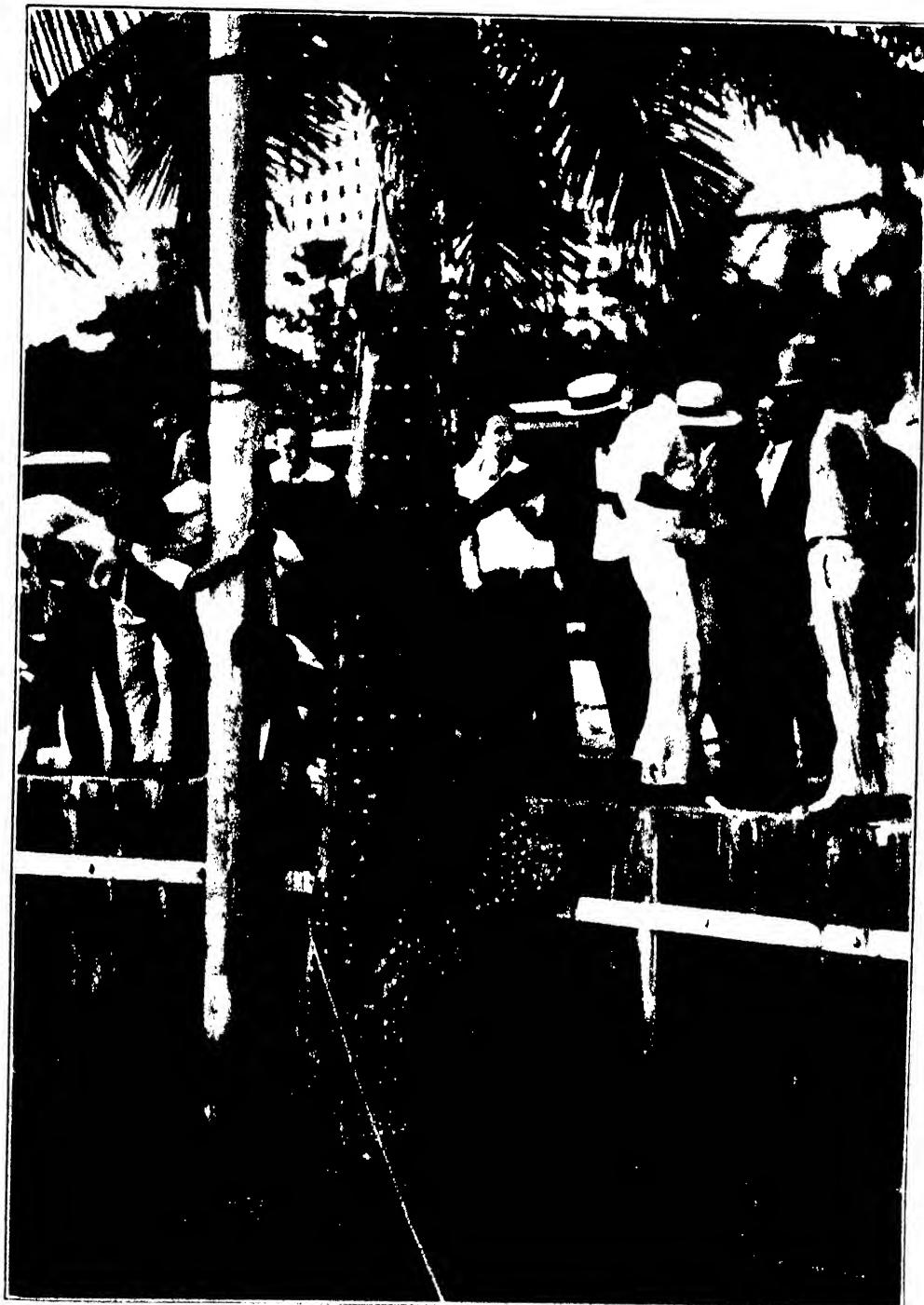
Adams, chief of the Division of Fisheries, Philippine Bureau of Science, Manila. The specimen shown therein was caught in a fish trap at Barrio Aplaya, Bauan, Batangas, Luzon Island. It entered the trap on March 4, 1932, and died during the night of the 7th. It was measured by the local doctor, who found that it was 21 feet long (5.37 m) and had a girth of 13.5 feet (3.44 m). The shark had unfortunately been towed out to sea and sunk when Mr. Wallace's photographer and preparator reached the spot. Fortunately, however, a local photographer had taken a picture of it and a copy was procured by Mr. Wallace's aides. Fig. 7 is made from this. It shows the fish in lateral view as it was drawn out on the beach. The reader's attention is called to the small eye, the flat head, the long gill-slits, the spots and the longitudinal ridges.

In this connection, and in view of the fact that two photographs of the whale shark in the Philippines are reproduced herein, it will be of interest to state that this great fish seems probably to be more

abundant here than anywhere else in the world. This conclusion is based on 12 authentic records and about as many doubtful ones collected by Mr. Adams. He will shortly bring these data together and publish them. Perhaps it is not too much to hope that he may presently get better photographs than those from the Philippines reproduced herein.

Best of all the photographs are those of the 18-foot specimen captured off Miami, Florida, on January 18, 1932. I have put this specimen on record (*Science*, April 15, 1932) and now have pleasure in doing the same thing for the best of these photographs. Fig. 9 shows the anterior half of the fish resting on the ground with the tail partly suspended in the air. This shows the huge mouth and gullet in close view. If only a mirror had been used to light the interior of this cavern, it would have added greatly to the scientific value of the photograph.

In the magnificent photograph reproduced as Fig. 8 the fish is suspended clear of the water. This is a quartering lateral view which portrays nearly



--Photograph by courtesy of Miami Herald Studio
FIG. 8. THE MIAMI (1932) WHALE SHARK SUSPENDED BY THE TAIL
NOTE THE GENERAL FORM, THE CHAMFERINGS, AND ESPECIALLY THE BARS AND SPOTS.



—Photograph by courtesy of Mr. John Mills and Mr. Albert Pfueger
FIG. 9. HEAD-ON VIEW OF THE MIAMI WHALE SHARK, 1932
THE FISH, PARTLY LYING ON THE GROUND, HAS FLATTENED OUT VERY MUCH.

everything one wishes to see in the fish—the general shape, the fins, the lateral keels and chamferings, and the remarkable color-pattern. One wishes that the tail could have been held flat in the vertical-longitudinal plane of the body so that the conformation of the lobes would have been shown. Another photograph looking squarely at the median

plane of the body would have shown the shape of the snout, head and shoulder-parts—all great desiderata.

I have two photographs taken at practically this angle, but the better for reproduction is that (Fig. 8) sent by the studio of the *Miami Herald*, and my hearty thanks for it are hereby expressed.

THE PROGRESS OF SCIENCE

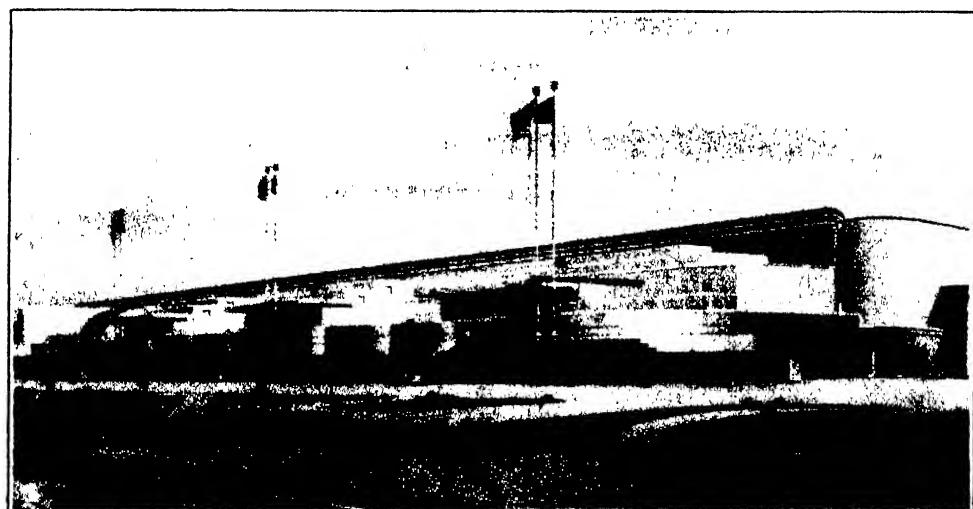
APPLIED SCIENCE AND INDUSTRY AT "A CENTURY OF PROGRESS" EXPOSITION

THE name, "A Century of Progress," was selected as descriptive of the theme of the exposition, which is to exhibit and portray to the peoples of the world the nature and significance of scientific discoveries and inventions based thereon, and the changes which the applications of scientific discoveries and inventions have wrought in industry and in living conditions during the past century.

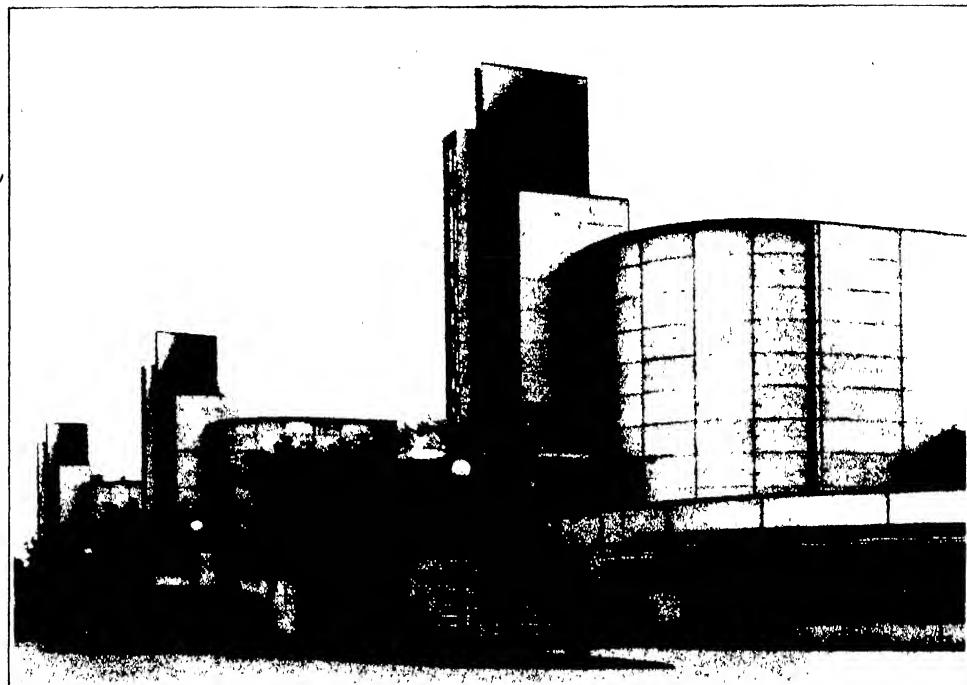
In order that the exposition might have an appropriate scenario for its theme, the National Research Council was requested to appoint a Science Advisory Committee to prepare reports not only as to what should be portrayed by the basic science exhibits but also what should be included in the exhibits to show the application of scientific discoveries in industry. These reports have served as a basic guide in seeking the participation of industry.

It is the function of the Applied Science and Industry Division to secure the participation of industry in a manner in keeping with the theme of the exposi-

tion. In general, men with experience in the various branches of industry have been placed in charge of appropriate sections and have developed their work with the advice and cooperation of the members of the Basic Science Division staff. This cooperation has been mutually helpful. The first approaches to nearly all industries were made with a view to securing group participation from the industry. This plan succeeded with several industries. With many industries, however, either because the members of the industry were highly competitive among themselves, or because the financial condition of a large proportion of the membership was poor, the group plan had to be dropped and the plan to secure the same type of exhibits from the leading corporations in the industry substituted. The officials of many large corporations quickly grasped the idea that an exhibit in keeping with the theme of the exposition would be far better prestige advertising for them than exhibits of their products.



THE AGRICULTURAL BUILDING OF THE AGRICULTURAL GROUP
IN WHICH A NEW KIND OF FOOD AND FARM IMPLEMENT SHOW WILL ATTRACT BOTH FARMER AND
CITY DWELLER.



PAVILIONS OF THE GENERAL EXHIBITS GROUP

WHICH WILL CONTAIN THE EXHIBITS OF THE MINERAL INDUSTRIES AND INDUSTRIAL ENGINEERING RELATED THERETO, AND THE HISTORICAL AND PROCESS EXHIBITS OF THE GRAPHIC AND INDUSTRIAL ART INDUSTRIES.

The Applied Science and Industry Exhibits will, in general, portray the application of scientific discoveries in the industry, features of historic interest, processes of manufacture, final products and the effects of the development of the industry on living conditions in cities and on farms. The work of engineers is shown as an integral part of the industrial exhibits instead of something segregated and set apart by itself. The exhibits are non-competitive and no prizes are awarded. Certificates of participation will be presented to exhibitors. From the nature of the exhibits, applicants who wish to present single articles for exhibition are barred unless they can have the articles incorporated as a part of a large exhibit where they fit into the stories being presented and have some meaning.

The Applied Science and Industry Exhibits are arranged in six grand groups, as follows:

(1) The Travel and Transport Group includes exhibits of transportation by rail, highway, waterway and in the air, together with exhibits by the associated industries such as the manufacturers of railway equipment and supply, automotive equipment and supply, etc. Travel features, both foreign and domestic, are stressed.

(2) The Electrical Group includes exhibits of the manufacture of electrical machines; the generation, distribution and utilization of electrical power, the applications of electricity in communication, and the utilization of electricity in radio transmission.

(3) The Agricultural Group includes exhibits of food products, farm machinery and equipment, dairy products and poultry.

(4) The Medical and Chemical Group includes exhibits from manufacturers of articles which serve the medical professions and from the closely associated manufacturers of chemicals. These exhibits will be shown in the Hall of Science in proximity to the scientific exhibits in medicine and under the same roof with the other basic science exhibits.

(5) The General Exhibits Group includes the exhibits of the mineral industries and industrial engineering related thereto and the his-

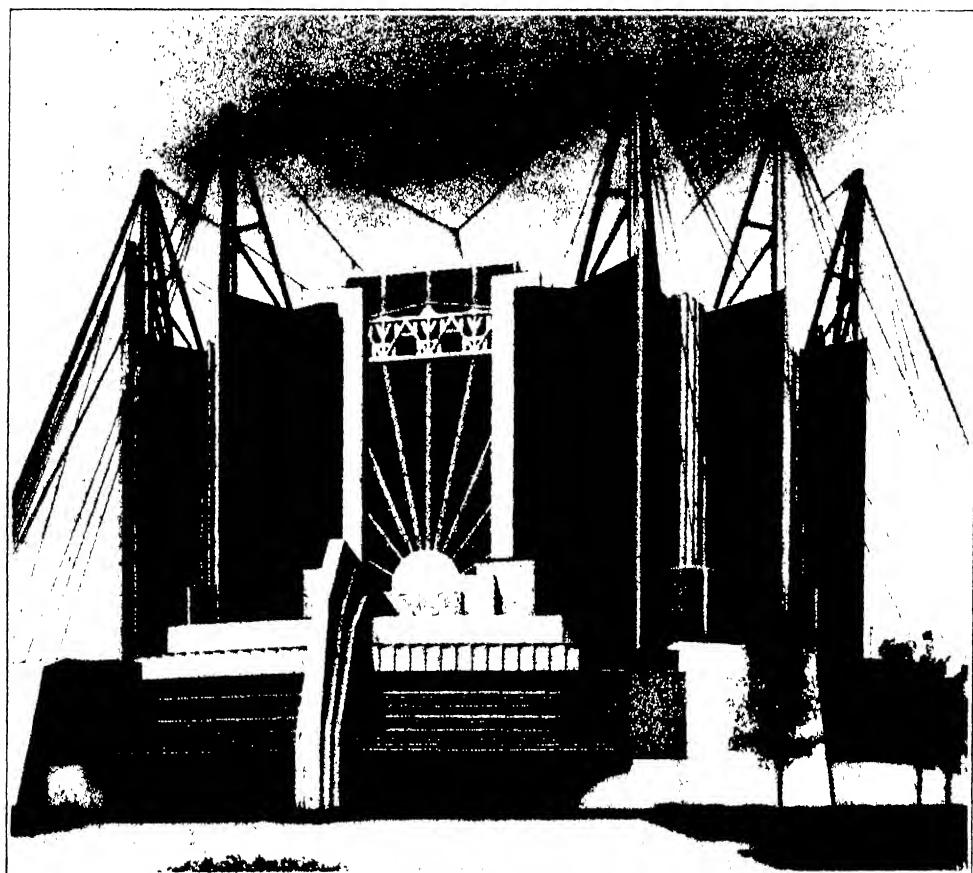
torical and process exhibits of the graphic and industrial art industries.

(6) While the above five grand groups provide a place for the exhibits of any industry, the need was felt for another group where the applications of any industry in the home and municipality could be more effectively portrayed in conjunction with the products of other industries. So a Home and Industrial Arts Group was created. Here new materials and methods of construction, the genius of interior decorators and home planners, the work of municipal and sanitary engineers and the products of those manufacturers who featured home furnishings and equipment will be on view.

Four months prior to the opening date of the exposition the work of securing the participation of industry necessary to present the applied science and in-

dustry exhibits is 80 per cent. completed. It is estimated that the expenditures for exhibit space and special buildings by exhibitors will reach a total of approximately \$6,000,000 and that additional expenditures for the preparation, installation and maintenance of exhibits will total from \$8,000,000 to \$10,000,000. Industry will present to men of science and to all visitors a marvelous display of what research engineers and the officials of industry have done in applying the discoveries of men of science to develop industries and improve living conditions.

J. FRANKLIN BELL,
*Chief, Applied Science
and Industry Division*



THE TRANSPORTATION DOME.

IN THIS UNIQUE STRUCTURE, ERECTED ON THE PRINCIPLES OF A SUSPENSION BRIDGE, WILL BE HOUSED EXHIBITS PORTRAYING THE DEVELOPMENT OF TRANSPORTATION DURING THE PAST CENTURY. THIS DOME, 310 FEET ACROSS THE BASE AND WITH AN UNOBSTRUCTED INTERIOR HEIGHT OF 124 FEET, IS THE CENTRAL FEATURE OF THE TRAVEL AND TRANSPORT GROUP.

**DR. HENRY FAIRFIELD OSBORN, RETIRING PRESIDENT OF THE
AMERICAN MUSEUM OF NATURAL HISTORY¹**

"Quaeris monumentum, circumspice," said Augustus Caesar, as the stately columns of the Eternal City rose beneath his approving eye. "L'état, c'est moi," quietly observed the Grand Monarch as he signed the order to make the dirt fly for the foundations of the magnificent palace of Versailles. History is silent as to the words of Cheops when he completed the greatest archeological exhibit of antiquity; but fortunately there will be no lack of publicity on the occasion of the completion of the new wings of the American Museum of Natural History. Even from the trough of the depression we may raise thanks that this country is still producing monument builders of the caliber of J. P. Morgan, John D. Rockefeller and Henry Fairfield Osborn.

There was once a stern ruler of the metropolis who denounced the Interests, defied the Plutocrats, scorned Aristocrats and booed at Experts; but Professor Osborn, an almost officially accredited representative of these proscribed classes, went and spoke soothingly to him of science, of education, of the millions of future citizens that the museum feeds with spiritual enlightenment and love of the beautiful, *et cetera, et cetera*. To his infinite credit Mayor Hylan (for it was he) became Professor Osborn's devoted backer and supporter, working valiantly with him to secure for the museum the buildings and maintenance that were urgently necessary for its civic functioning.

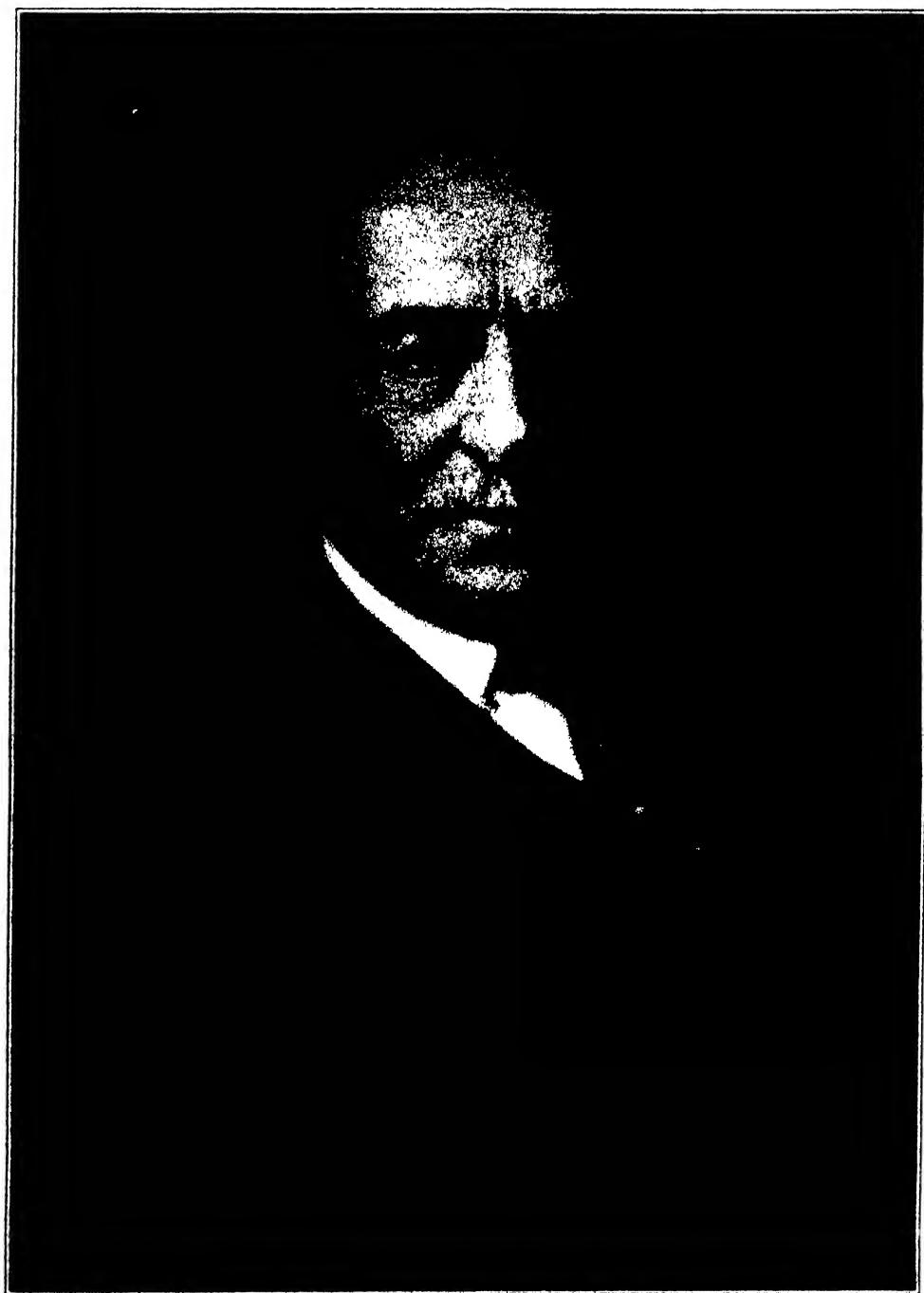
So it has been through the fifty-odd years of Professor Osborn's career as a builder—at Princeton, at Columbia, in

the New York Zoological Park, at the American Museum and as president of the Roosevelt Memorial Commission. Temporary opposition has only spurred him on to greater effort and one triumph has but opened the way to the next.

But let it be distinctly understood, President Osborn differs widely from Louis XIV and from Cheops precisely in that he does not aspire to run a one-man show or build a monument with his name alone inscribed thereon in bronze or granite. He has always been a leader, yes, but a leader of men whose names he delights to honor, brave companions in arms who have shared his triumphs with him and in whose achievements the old general takes the most generous satisfaction. Such a blue-eyed field commander, after his own heart, is Roy Chapman Andrews, who carried the flag of the American Museum into the deserts of central Asia and there opened up the astonishing new world of Ancient Mongolia. But what inspired Andrews to go there were Professor Osborn's professional prophecies, first uttered in 1899 and 1900, that central Asia would some day be found to be the home of many families of mammals, families which during the long ages of the Age of Mammals sent out colonists to western Europe and western North America and left their fossil bones to fill the great halls of the American Museum of Natural History. And what enabled Andrews to raise the funds for this scientific invasion of the Gobi Desert were not only his own brilliance and daring but the powerful backing of his beloved chief.

Walter Granger and Barnum Brown are equally trusted lieutenants of Professor Osborn—tall, quiet men, who move deliberately over great fields and call up long dead hosts from ancient battle-fields. And great is Professor Osborn's joy when among the younger

¹ In view of the recent retirement of Dr. Henry Fairfield Osborn as president of the board of trustees of the American Museum of Natural History this note of appreciation of his services to the Museum and of his personal characteristics has been prepared at the request of the editor.



Pach Brothers

DR. HENRY FAIRFIELD OSBORN
RETIRING PRESIDENT OF THE AMERICAN MUSEUM OF NATURAL HISTORY.

men he discovers one like Dr. George Gaylord Simpson, to whom he can confidently entrust the huge paleontological investigations of the next generation.

The same generous, friendly spirit has animated Professor Osborn's personal and family life. His wife, Lucretia Perry Osborn, was also his complete partner, who shared with him every civic and scientific labor and every triumph. She was truly the "Spirit of Castle Rock," their residence at Garrison, New York, and no guest of theirs will ever forget a visit with them. And now his sons and daughters and grandchildren rejoice that at seventy-six he labors on with undiminished zest.

Fortunately it was not because of failing power that Professor Osborn resigned the presidency of the board of trustees of the American Museum of Natural History, but because he had discovered among his younger associates a man whom he recognized as able and willing to carry the great burden of that office. It was no mere gesture then when Professor Osborn, on the occasion of the inauguration of Mr. H. Trubee Davison as his successor, spoke of the world-wide explorations of the museum and then suddenly picked up a large terrestrial globe and placed it in Mr. Davison's momentarily hesitant arms.

And it is no wonder that the latter spoke feelingly of his realization of the magnitude of his task. But all those who know well both Professor Osborn and Mr. Davison have the greatest confidence in the result. And both the honorary president, the new president and the board of trustees will doubtless continue to entrust the entire internal management of their ship to Director George H. Sherwood, who has long been responsible for the smooth working of its vast and complicated machinery.

Thus Professor Osborn will now have more leisure to devote to the completion of the series of monographs for which he has long been justly famous among the paleontologists of the world. The monograph on "The Evolution of the Titanotheres," published in 1929 as the result of twenty years' work, numbered 953 pages and included 797 text figures and 236 plates. The monograph on "The Proboscidea," now nearing completion, will make even the Titanothere monograph look small. Meanwhile among the almost nine hundred numbers of his scientific writings, the "Age of Mammals," "Men of the Old Stone Age" and "The Origin and Evolution of Life" continue to hold a deservedly high place in the estimation of his admiring public.

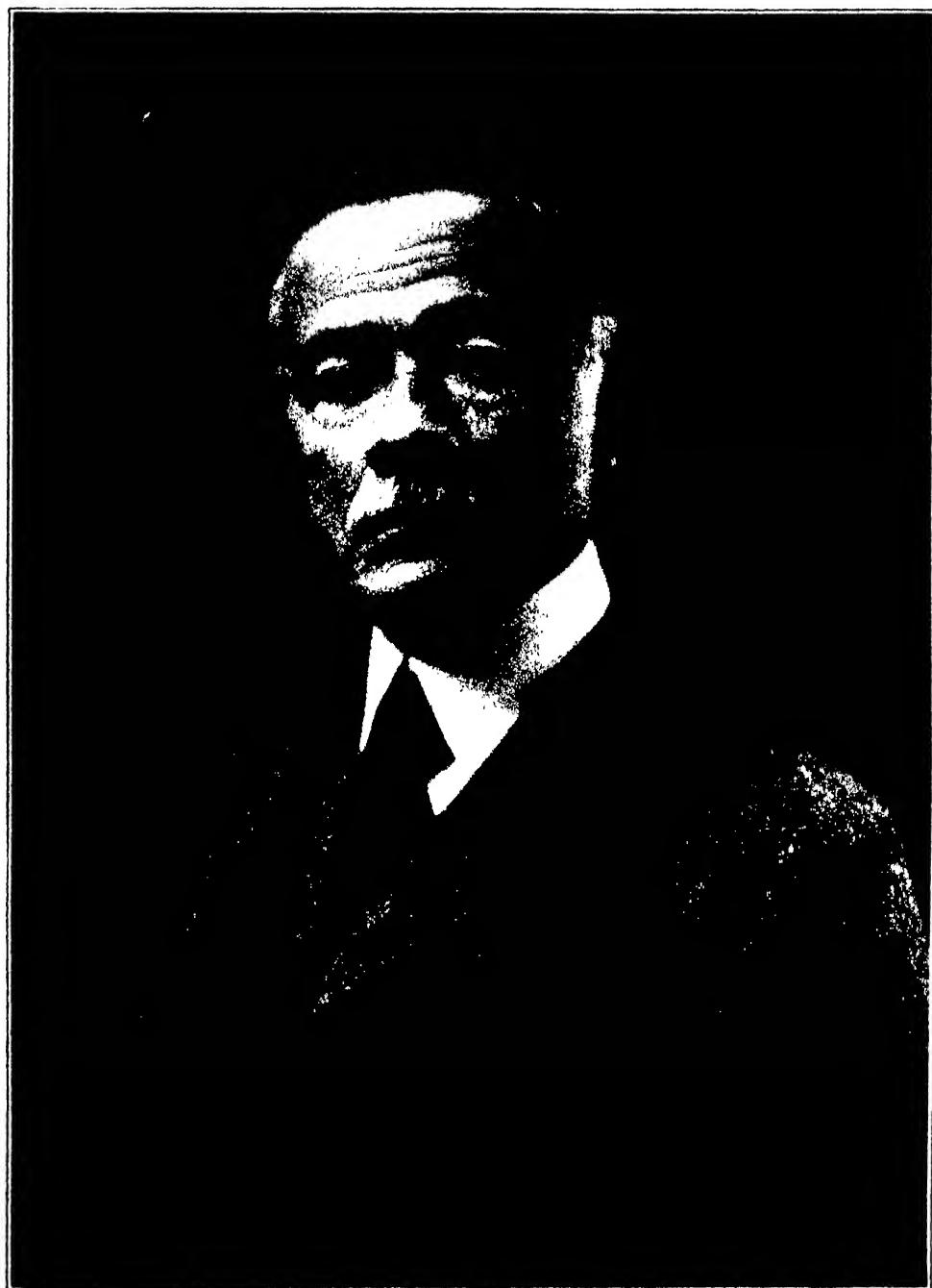
JOHN JOSEPH CARTY

DR. JOHN J. CARTY, pioneer in the development of the telephone art since its early days, died on December 27 at the Johns Hopkins Hospital. Born in Cambridge, Massachusetts, in 1861, Carty completed a course in the Cambridge Latin School and in 1879 began his telephone career, three years after the telephone's invention, when he entered the employ of the Telephone Dispatch Company of Boston. His natural ability and his fondness for scientific investigation led to a long series of valuable contributions to the advancement of the

telephone art. Concerning them Dr. F. B. Jewett writes in *Science*:

"His invention of the 'common battery' for supplying operating current from a single central office battery to any number of interconnected telephones made practical the commercial development of telephony in metropolitan areas.

"His development of the high resistance bridging signal bell for subscribers substations to replace the theretofore universally employed low resistance series bell, tore the hampering shackles from a wide-spread extension in the use



JOHN JOSEPH CARTY
1861-1932

of the telephone. Every telephone set now in use employs such a signal.

"Equally revolutionary and of a more distinctly scientific character was his discovery that the principal cause of cross interference between telephone circuits was electrostatic and not electromagnetic unbalance. This discovery and the rules which General Carty worked out for the proper construction of adjacent telephone circuits are now universally employed."

Many important engineering problems confronted General Carty during the years while he served as chief engineer of the American Telephone and Telegraph Company. Perhaps the most notable of these was the completion in 1915 of the transcontinental telephone line which made possible the first transmission of speech between the Atlantic and Pacific coasts and thus achieved a dream which Carty himself had long cherished—nation-wide telephone service. Shortly after this achievement was announced, engineers working under Carty's direction accomplished the first successful transmission of speech by radiotelephone from New York to San Francisco, to the Hawaiian Islands and to Paris—the pioneer efforts in the development of a system of radiotelephone facilities which now are practically world-wide in their reach.

In 1919 General Carty was elected vice-president of the American Telephone and Telegraph Company in charge of the department of development and research. In 1925 he was also made chairman of the board of directors of the Bell Telephone Laboratories. He retired from active participation in telephone work in 1930.

Among the scientific and engineering awards which have been granted to General Carty are: The Edward Longstreth Medal, the Franklin Medal for eminent service in science, the Edison Medal for "work in the science and art of telephone engineering," the John Fritz Gold Medal "for pioneer achievement in

telephone engineering and in the development of scientific research in the telephone art." The National Academy of Sciences established the John J. Carty Medal in his honor, and made the first award to him, the actual presentation of which was to have taken place at its annual meeting in April.

In his tribute Dr. Jewett writes:

"General Carty had an insatiable desire to enlarge his own fund of information and understanding. All who came in contact with him, from the most wise to the most frivolous and shallow, were subjects for his inquiry. He gave much and willingly of his store of knowledge and wisdom but in return, and frequently in ways unknown to his vis-à-vis, he exacted payment in full measure. At times this payment was in kind; more frequently than not it was in values quite foreign to the main subject-matter of the conversation. At the termination of the contact General Carty had invariably something new added to his already great store of knowledge—a bit of social history or custom, a hitherto unknown item of science, a peculiar slant of political thinking, or any other of the thousand and one things which involve the working of human emotions or the human mind.

"His relentless search into the way human beings react and into the motives which guide their thought and action, and whose results he continually marshaled and remarshaled under the guidance of his incisively analytical mind, became a main source of his extraordinary capacity for being always at home in any company. Few men possess the capacity which General Carty had for meeting on a plane of complete understanding men and women of every social and intellectual gradation. It was a capacity which enabled him in every situation to give and receive knowledge and to influence the outcome of events in ways and in a manner which were frequently uncanny."

QUANTUM MECHANICS AND CHEMISTRY

FOR nine successive years the American Association for the Advancement of Science has awarded a prize of one thousand dollars for a notable contribution presented at its annual meeting. The prize for 1932 was awarded at the Atlantic City meeting of the association to Dr. Henry Eyring, of Princeton University, for the paper presenting his theoretical calculations of rates of chemical reactions.

Life processes, in fact practically all changes, are a result of chemical reactions so that any progress toward a better understanding of chemical processes is of very general interest. It is a familiar fact that most reactions approximately double their rate for a temperature rise of ten degrees. Practical application of this fact is made, for example, in the preservation of foods by refrigeration. A chemical reaction consists in an atom exchanging one of its partners for a new one. An atom which has the normal complement of companion atoms allows additional atoms to approach it only with the utmost difficulty. In fact, this is only possible in the case of rare cataclysmically violent collisions. At any attainable temperature these very violent collisions are rare, but the number increases with a rise in temperature. The energy with which two molecules must collide in order to change partners is called the activation energy and the critical configuration is called the activated state.

The method of calculating how frequently collisions of a specified violence occur is well known, so that if we can predict how energetic a collision is required for a given reaction we can calculate the rate of the reaction. It is just this problem of calculating activation energies which Dr. Eyring has attacked, using the quantum mechanics.

Starting with two molecules, it may be possible to form the same new molecules by a great variety of intermediate steps. Thus one of the molecules may

first break up into atoms, after which one of the atoms may react with the second molecule or the two molecules may react in a single process. The process most economical of energy will be the one which actually occurs so that theoretical calculations suffice to indicate the actual process. Calculation and experiment agree in all the cases investigated. Another interesting result of the calculations is that hydrogen and fluorine do not react at ordinary temperatures in agreement with the newest experiments but contrary to the much quoted older ones. The method has given a satisfactory picture of certain reactions occurring on surfaces and shows why in general the lighter of two isotopes should be slightly more reactive. This latter effect should be useful in the separation of isotopes. The calculations also exclude certain proposed mechanisms in the photochemical reaction of hydrogen with chlorine, in which case again it agrees with the most recent experimental results. Dr. Eyring's newest calculations serve to explain why both hydrogen and bromine add to the two end carbon atoms of butadiene. Butadiene is the simplest example of what is known to chemists as a conjugate double bond system. The method thus appears capable of dealing with rather complicated molecules. Indeed the difficulty in applying the method depends on the complexity of the chemical change which occurs rather than on the complexity of the molecules reacting, since atoms remote from those which are reacting play an insignificant rôle.

Dr. Eyring states that "there is thus accumulating an empirical foundation for the method more compelling than that which may at present be adduced from strictly theoretical considerations. The qualitative correctness in all cases of the calculations indicate that it is a surprisingly powerful tool with which to attack the almost endless variety of problems of chemical mechanism."

MEASUREMENT OF THE COUNTERGLOW

IN the dark night sky, when one is far away from city glare, it is sometimes possible to detect a faint patch of light, in a position directly opposite that of the sun. This is called the "gegenschein," or counterglow, and is due to the reflection of sunlight from a swarm of minute particles far out in space. Though even the ancient astronomers could probably have seen it if they had looked, its discovery was actually not recorded until 1885 by a German astronomer named Theodor Brorsen. Now the "electric eye" again rivals its human counterpart, not only in permitting scientists to detect the gegenschein, but also in measuring its brightness. Dr. C. T. Elvey, of Yerkes Observatory, has just announced, according to Science Service, the results of his study of this faint object with a photoelectric cell attached to the Yerkes 40-inch refractor telescope.

Dr. Elvey's method was to point the telescope to a part of the sky nearly free from stars, and just to the north or south of where the gegenschein should be. Even the night sky is not entirely dark, so a small amount of light fell on the photoelectric cell, producing a minute electric current, which was detected on an electrometer. Then the instrument was moved toward the gegenschein, and another reading taken. This process was continued, readings at regular intervals being made along a north and south line, until the gegenschein was well passed. When these data were plotted, the curve showed a bump, which was due to the extra light from the glow itself. Then Dr. Elvey took a series of readings along parallel north and south lines in the sky, to one side, through and to the other side of the glow. This gave the brightness of a series of points in the

sky, and when these were drawn in their proper positions, and those of equal brightness connected, the lines showed a roughly elliptical area outlining the gegenschein.

He has found that the total brightness of the object is about that of a star of the minus .28 magnitude, brighter than any seen from these latitudes except Sirius, the dog star. But instead of being concentrated in a point, like the star, this amount of light is spread over an area as large as many an entire constellation. At the center, where brightest, the intensity is equal to that of a star of 6.2 magnitude, just below naked eye visibility under any but the best conditions.

Dr. Elvey's measures show that the gegenschein is egg-shaped, and is from 22 to 35 degrees in length and 21 to 26 degrees in height. A degree in the sky is about twice the diameter of the moon or sun. However, on one night when the observations were being made, reports Dr. Elvey, the gegenschein appeared only about half as large as indicated by the measurements.

The particles which cause the gegenschein are distributed around the sun in the shape of a lens, and extend out beyond the earth's orbit. They also cause the zodiacal light, which is much more easily seen. The phenomenon appears after sunset or before sunrise, as a faint, tapering beam of light, extending along the sun's path for perhaps 90 degrees from the sun.

The gegenschein can best be seen at midnight, for then it is highest in the sky. At certain times of the year it is blotted out by the Milky Way. It is well away from the Milky Way in October and November, the best months for observing it.

THE SCIENTIFIC MONTHLY

APRIL, 1933

The Scientific Work of the Government of the United States

SCIENTIFIC ASPECTS OF THE WORK OF THE DEPARTMENT OF STATE

PREPARED FOR THE SCIENTIFIC MONTHLY BY THE DEPARTMENT OF STATE OF THE FEDERAL GOVERNMENT

ON July 27, 1789, President Washington approved an act entitled "An Act for establishing an Executive Department, to be denominated the Department of Foreign Affairs." As defined in this act, the functions of the new Department were confined exclusively to the management of foreign affairs; however, on September 15, 1789, a supplementary act was approved extending the functions of the Department into the domestic field and changing its name from the Department of Foreign Affairs to the Department of State.

In the early days of its existence, the Department had certain duties which, with the passage of time and the creation of new executive departments, have long since been transferred elsewhere. Several of these functions partook of a scientific character. Thus, by an act of April 10, 1790, the Department of State was given control over patent matters. At first, patents were granted by a Board, composed of the Secretary of State, the Secretary of War, and the Attorney General; but in 1793, another act relating to patents was passed abolishing the Board and placing the Secretary of State alone at the head of the Patent Office. This arrangement held good until 1849 when,

with the establishment of the Department of the Interior, control over patent matters passed to that Department.

From 1790 until 1850, or for a period of 60 years, the Department of State supervised the taking of the decennial census. In the latter year, this work also was transferred to the newly created Department of the Interior, whence it was again transferred to the Department of Commerce and Labor only to come to rest at last in the Department of Commerce.

Another of the early duties of the Department was the management of the mint. Mr. Jefferson, early in his tenure as Secretary of State, transmitted to the President for his consideration two experimental coins made "by putting a silver plug worth three-quarters of a cent into a copper worth one-fourth of a cent." In view of the variety of these duties, one can understand Jefferson's remark that the Department of State embraced "the whole domestic administration (war and finance excepted)."

But these early activities, while interesting to recall, no longer form a part of the work of the Department, which, though still retaining some duties of a domestic character, is now, as was orig-

inally intended, almost exclusively concerned with the management of the country's foreign relations. The term "foreign relations," however, is a very comprehensive one and includes within its scope relations concerning problems of a scientific nature as well as those touching on economic or political matters.

The Department of State, unlike certain of the other executive departments, is not engaged directly in scientific pursuits. Its activities in behalf of science arise largely, though not exclusively, first, from the fact that the Government of the United States contributes an annual quota toward the maintenance of a number of international bureaus or commissions located abroad, about half of which are concerned with work of a scientific nature and, secondly, from its duties in connection with the many international conferences or congresses, a large percentage of which are of direct interest to science in one field or another.

Included among the international scientific agencies to which this Government contributes is the International Bureau of Weights and Measures. The work of this Bureau, which is located at Paris, consists in making all comparisons and verifications of the standard meter and kilogram. It has the custody thereof and makes other comparisons and verifications dealing with weights, measures and electrical units. The international meter and kilogram, adopted by the Treasury Department in 1893, are the basic standards of length and mass in the United States. The instruments of the Bureau of Standards at Washington are copies of those kept by the International Bureau of Weights and Measures and are sent from time to time to Paris for comparison with the originals, thus maintaining a constant standard in this country for instruments used in boundary measurements, surveys and triangulation.

This Government has also maintained membership for many years in the International Institute of Agriculture, an institute located at Rome which furnishes member states with data on the various factors determining the prices of agricultural produce in the world's markets, and acts as a clearing house for information on economic, scientific and technical problems affecting world agriculture.

Similarly, support is given to the Pan-American Sanitary Bureau and the International Office of Public Health. Both agencies are concerned primarily with the problem of the international control of communicable disease, the sphere of action of the former being North and South America, while the latter is most directly interested in the problem so far as it affects the countries of Europe.

Under authority of an Act of Congress, approved on May 7, 1928, the United States through the Department of State contributes an annual sum to the Gorgas Memorial Laboratory. This laboratory is maintained in connection with the Institute of Tropical and Preventive Medicine, the seat of which is at Washington, and constitutes a center for research in the field of tropical disease.

The International Hydrographic Bureau, with headquarters at Monaco, performs an important function in effecting a close and permanent association between the hydrographic services in the adhering states. It aids in coordinating their efforts and facilitates the adoption by national hydrographic offices of resolutions taken by the international hydrographic conferences which meet from time to time. It seeks to obtain uniformity, so far as is possible, in hydrographic documents and furthers in many ways progress in the theory and practise of the science of hydrography.

Another of these international scientific bureaus, the American International

Institute for the Protection of Childhood, was established in 1927 as a consequence of the Pan-American Child Welfare Congress held in Santiago, Chile, in 1924. It has for its object the collection and publication of laws, regulations and other documents concerning the protection of children; the publication of official reports and studies concerning the interpretation and execution of such laws; the collection of records of organizations and institutions pertaining to children; and the recording of statistics, charts and general conclusions.

This Government contributes also toward the expenses incurred by the Central Bureau of the International Map of the World, a bureau located at Southampton, England, having for its purpose the standardization of a world map. The Bureau publishes an annual report made by each of the member states as to the compilation and publication of sheets conforming to the standard specifications, besides providing a medium for the exchange of information of value to the adhering countries.

The Permanent International Association of Road Congresses, with offices at Paris, was established in 1908 and consists of delegates of governments and organizations of all countries subscribing annually to its support, of which the United States is one. The object of the association is to promote progress in the construction, traffic and exploitation of roads by organizing periodic international road congresses; publishing papers, proceedings and other documents; and by collecting and disseminating the results of tests, both road and laboratory, of materials used in road construction and maintenance.

Of particular interest to scientists is the International Commission on Annual Tables of Constants, to which this Government has contributed annually for a great many years. The work of this commission consists in the collection and

annual publication in tabular form of the quantitative results of research in chemistry, physics, biology, and applied branches. It is obviously important that the same constants be used in all countries in order that scientific and technical papers and reports may be understood in other countries than those in which they are published. Any new values which are determined are collected by the International Commission and made available in the annual tables.

Mention should also be made of the International Council of Scientific Unions, established at Brussels. The following list of member societies indicates the wide range of problems in the purely scientific field dealt with in the council: The International Astronomical Union; the International Union of Chemistry; the International Union of Geodesy and Geophysics; the International Scientific Radio Union; the International Union of Physics; and the coordinating agency in International Council of Scientific Unions. In view of the fact that scientific investigation is being carried forward along like lines in many countries, it is obviously in the interest of both economy and progress in research that the investigations be coordinated and their results disseminated to scientists throughout the world.

The rapid strides made in comparatively recent years in improving and expanding the world's communication and transportation services have resulted, among other things, in bringing home most effectively to the nations of the world the fact of their essential interdependence. This realization has in turn brought about quite naturally a marked increase in the number of international conferences of which a very considerable number are concerned with scientific problems.

Taking, for example, the period from July 1, 1929, to June 30, 1932, out of 160 conferences in which this Government participated officially, 69 met to

discuss questions of direct scientific interest. It would obviously be impossible within the limits of this article to mention in detail all of these. Some idea, perhaps, of the wide range of subject-matter covered in these meetings can be gained from the following list of conferences taken more or less at random from among those held recently: Ninth International Horticultural Congress; Fifth International Botanical Congress; Eleventh International Congress of Zoology; Inter-American Conference on Agriculture; Fourth International Congress of Geometricians; Third International Conference for Photogrammetry; Eighth Congress of the Far Eastern Association of Tropical Medicine; Fifteenth International Congress of Agriculture; Sixth International Congress of Military Medicine and Pharmacy; Eighteenth International Congress of Orientalists; International Congress of Geography; Second Congress of Comparative Pathology; and Third International Hydrographic Conference.

Among conferences of a scientific character scheduled to convene in the near future are the Sixteenth Session of the International Geological Congress, which will meet in Washington this coming June; the Seventh International Congress of Military Medicine and Pharmacy, to convene this summer at Madrid; the Fourteenth Concilium of Ophthalmology; and the Fifth Pacific Science Congress, scheduled to be held in Victoria and Vancouver, British Columbia, in June of this year.

Geography is a science which, since 1920, has been directly recognized in the organization of the Department of State. The Office of the Geographer, besides compiling maps, some of which have been published by the Department—notably those of Manchuria and China—is responsible for the geographic phases of

all matters under consideration by the Department. From time to time, however, special studies are required, such as the historical and geographical study made in connection with the determination of the national origin immigration quotas, now in effect. These researches which extended over a period of three years were necessary in order to bring the statistical tables of the United States Census into conformity with the present-day boundaries in Europe. The Office of the Geographer was also concerned in the preparation of the "First Report on Foreign Geographic Names," published by the United States Geographic Board in 1932.

The Department of State is frequently called upon to assist in making the necessary arrangements for American institutions to carry on scientific explorations and researches in foreign countries. Among the more recent expeditions of this sort facilitated by the Department might be mentioned the present exploration being carried on in the West Atlantic Deeps by the Smithsonian Institution, under the direction of Dr. Paul Bartsch; the International Scientific Expedition to the Bahamas in 1932, under the auspices of Princeton University; and the Botanical Expedition to Colombia, composed of representatives of the Johns Hopkins University and the University of Pennsylvania.

This article would scarcely be complete without at least reference to the work of the American consular and diplomatic officers in sending to the Department reports on the results of scientific investigations being carried on abroad and on matters of general scientific interest, reports which the Department transmits to interested departments of the Government as well as to private organizations concerned.

RESEARCH WORK OF THE BUREAU OF RECLAMATION

By Dr. ELWOOD MEAD

COMMISSIONER OF RECLAMATION, UNITED STATES DEPARTMENT OF THE INTERIOR

THE Bureau of Reclamation of the Department of the Interior was established by the Reclamation Act of June 17, 1902. By this act, revenues received from the sale and disposal of public lands in the Western states were set aside in a special fund known as the Reclamation Fund to be used in the construction of irrigation works for the storage, diversion and distribution of water for the reclamation of arid and semi-arid lands in the West. The Reclamation Fund is a revolving fund, and the expenditures from it for constructing irrigation works, including costs of surveys and investigations in connection with such works, become a charge against the lands benefited which must be repaid by the owners of these lands over a period not exceeding forty years.

During the thirty years of its life, the bureau has examined and surveyed numerous irrigation projects located throughout the seventeen Western states, and has constructed and operated in whole or in part thirty-two adopted projects. Many features in the design and construction of these irrigation projects have involved unprecedented dimensions, conditions and methods, and have led into fields of engineering of a pioneering nature. The engineers of the bureau have often found that previous theory, practice and experience in design and in construction methods were inadequate. Such findings have emphasized the need for constant research and investigation into new methods of design and construction. These researches and investigations have been conducted as thoroughly and extensively as possible, but due to the limitations of available

funds they have not been as complete or extensive as desirable. Practically no funds have been available for pure research work, and as all expenditures from the Reclamation Fund are reimbursable the money expended for research investigation must in every case be restricted to the amount which can properly be charged to the design or construction of the particular project or feature for which the work is undertaken.

The irrigation projects of the bureau involve a great variety of construction work, including storage dams and diversion dams of many different types, power plants, pumping plants, canals, laterals, drains, conduits and canal structures of all kinds. The successful and economical design, construction, operation and maintenance of such works is greatly aided by proper engineering research. Likewise the determination of the economic feasibility of proposed irrigation projects is of prime importance and involves much work of a research nature, including investigations of the quality of soils, sufficiency of water supply, suitability of climatic conditions and the value of crops.

Many notable engineering works have been constructed on the completed projects, including several of the outstanding dams of the United States. Among these structures, constituting a progressive succession of the highest dams in the world, are Shoshone Dam in Wyoming, 328 feet high, and containing 78,600 cubic yards of concrete, which was completed in 1910; Arrowrock Dam in Idaho, 349 feet high, and containing 585,000 cubic yards of concrete, which

was completed in 1915; and Owyhee Dam in Oregon, 405 feet high, and containing about 536,000 cubic yards of concrete, which was completed in 1932. The bureau now has under construction the Boulder Canyon Project, the outstanding feature of which is Hoover Dam on the Colorado River near Las Vegas, Nevada, which will rise 730 feet above bedrock, or nearly twice as high as any previous dam, and with appurtenant works will contain about 5,000,000 cubic yards of concrete. As this project involves the most extensive and complete program of investigation and research yet undertaken by the bureau, this article will be largely confined to a description of the research work undertaken in connection with the design and construction of Hoover Dam and appurtenant works.

THE BOULDER CANYON PROJECT

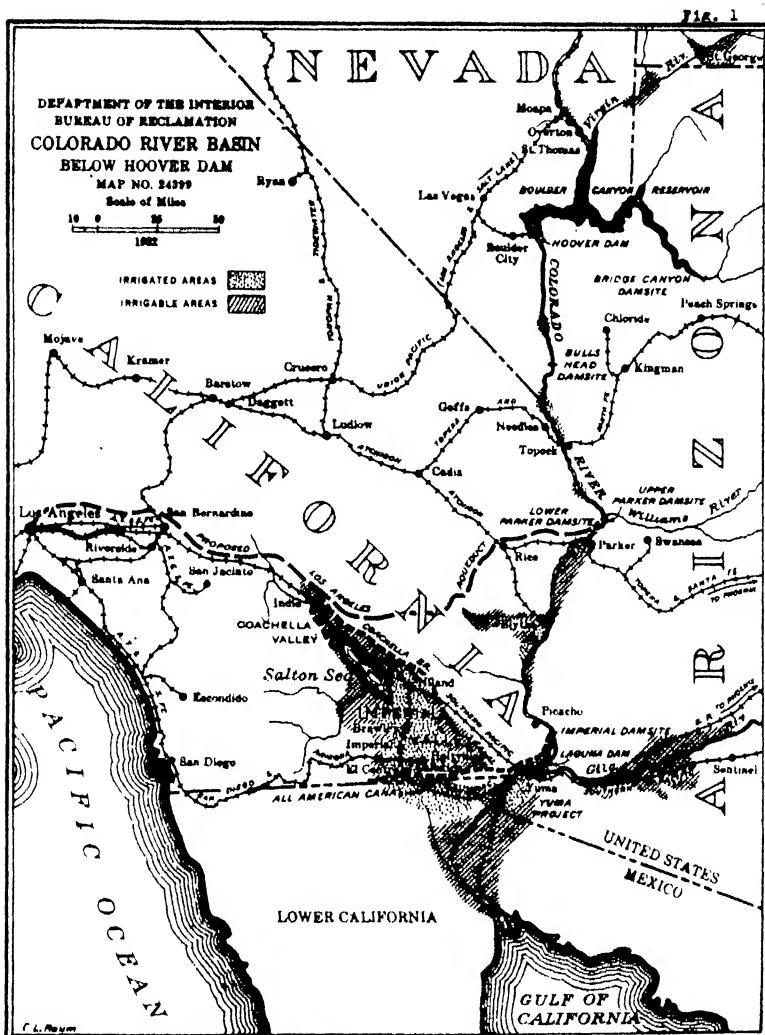
The conquest of the Colorado River which has culminated in the construction of Hoover Dam had its inception four hundred years ago when, in 1536, Cortez pawned his wife's jewels for necessary funds and sent Francisco de Ulloa to find the fabled seven cities of Cibola. Ulloa reached the mouth of the Colorado River in 1539 but there abandoned the search because of the thirty-foot tides which, as he recorded, "rush with great rage into the land." The actual discovery of the Colorado River took place in 1540 when Alarcon entered the river at its mouth and ascended it in boats for fifteen days. After this visit the assault on the river remained dormant for over three hundred years, except as it was touched by occasional Spanish explorers searching for routes to California and to the interior.

In 1857 Lieutenant Ives, of the Engineer Corps of the U. S. Army, attempted to prove the navigability of the river in the hope that it could be used for carrying supplies to the military posts at Salt Lake City, Utah, and Tucson, Arizona.

Starting in March, it was December when his steamboat *Explorer* reached the swift waters of Black Canyon, the site of Hoover Dam. After spending five days in traveling the last twenty miles he accepted Black Canyon as the ultimate head of navigation.

In 1869 Major John Wesley Powell, of the Geological Survey, made the first comprehensive exploration of the Colorado River and demonstrated the possibility of passing alive through the 1,000-mile stretch of heretofore impassable canyons. With the passage of the Reclamation Act in 1902, detailed investigations of the Colorado River were inaugurated, which were in succeeding years extended to cover the entire basin, with a view to disclosing all possibilities of water utilization for irrigation, flood control and power as a basis for a comprehensive plan of development. By 1924 the investigations had been completed far enough to demonstrate conclusively that the first major project in the control and development of the river should include the construction of a high dam in Black Canyon, which is twenty miles downstream from the site first investigated in Boulder Canyon, from which the project derives its name. This dam and reservoir will accomplish the fourfold purpose of flood control, storage of water for irrigation, removal of silt and power development. (Fig. 1.)

The undertaking of the Boulder Canyon Project under the direction of the Reclamation Bureau was authorized by the Boulder Canyon Project Act, which was signed by President Coolidge on December 21, 1928. This act authorized an appropriation of \$165,000,000 for the construction of: (a) A dam in Boulder or Black Canyon to store not less than 20,000,000 acre-feet of water; (b) a power plant, and (c) an All-American canal to connect the Colorado River with Imperial Valley. A fund known as the Colorado River Dam Fund, and separate



from the Reclamation Fund, was set up to finance the construction of the Boulder Canyon Project. The act provided that before actual appropriations could be made, contracts for the sale of power and water must be secured to insure payment of the cost of the dam and power plant with 4 per cent. interest in not more than fifty years.

All requirements of the act having been met, the initial appropriation for construction of the project was approved by President Hoover on July 3,

1930. This date marks the beginning of a new epoch in the history of the Bureau of Reclamation. During the first twenty-seven years of its activities the bureau had designed and constructed over one hundred dams, of constantly increasing importance, in addition to many other great engineering works. The Owyhee Dam might be considered as climaxing this progression in the construction of important though not extraordinary engineering works. The intrusting of the design and construction of Hoover Dam

to this organization places new and greatly increased responsibilities on the engineers of the bureau and marks a new chapter in the history of the design and construction of high concrete dams.

Nearly all the dimensions of Hoover Dam and its appurtenant works are of unusual magnitude, presenting many unusual problems that must be solved in the design, construction and operation of the project. Great caution must be exercised in applying previous theories and practises to the design and construction of a dam of these unprecedented dimensions. New theories and practises must be developed from fundamental data, and these must be checked, tested and proved in every possible way to insure that no mistakes are made in their development or application, and that the maximum economy is secured that is consistent with permanence and absolute safety. Recognizing these conditions, and considering the importance of the structure and the enormous expenditure involved, it was deemed imperative that a sufficient research program be undertaken to establish beyond question the suitability and sufficiency of the methods of design and construction to be adopted.

The research program for Hoover Dam is now in progress in nearly all its features, and while tentative conclusions have been formulated as the progress of construction has demanded, the final results and conclusions are not yet available for publication. It is possible, however, at this time to outline the purposes and scope of the investigations, which involve researches in many branches of science, including mathematics, mechanics, physics, hydraulics, seismology, structural geology, chemistry and related sciences. New methods and equations for the mathematical analysis of stresses have been developed from fundamental principles. New features of mechanical, structural and hydraulic design have been adopted. Improved methods and technique in model testing

have been worked out. Exhaustive studies have evolved new concepts of the structural and thermal properties of concrete, including the development of new specifications for Portland cement of controlled heat evolution, and many experiments and tests have been made under both laboratory and actual field conditions, to determine physical, structural and hydraulic properties.

Design of the Dam: Hoover Dam will be of the massive arch-gravity type, about 730 feet high and 650 feet thick at the base. (Fig. 2.) The pressure of the water on the upstream face at the base of the dam will be about 45,000 pounds per square foot, and the total pressure on the upstream face will be more than three and one fourth million tons. This pressure will be transmitted to and supported by the rock of the canyon walls, and of the foundation under the dam. Under such conditions the amount and distribution of the stresses in the dam as well as in the abutments and foundations must be known with certainty and the structure must be so proportioned as to support these tremendous loads with maximum safety and economy and with no possibility of destructive stresses being developed.

While the technical design of the dam is largely a matter of mathematical analysis, supplemented by model testing, it involves at the same time many problems of a research nature. Until recent years no adequate and satisfactory method of analyzing the stresses in massive arch dams was known. The trial load method of analysis, which is now widely accepted as the best available method, has been gradually evolved by the engineers of the bureau, and this method has recently been brought to a highly satisfactory working state in connection with the design of Hoover Dam. The accuracy and dependability of this method of analysis has been established by field observation and particularly by model tests, which have proved conclu-

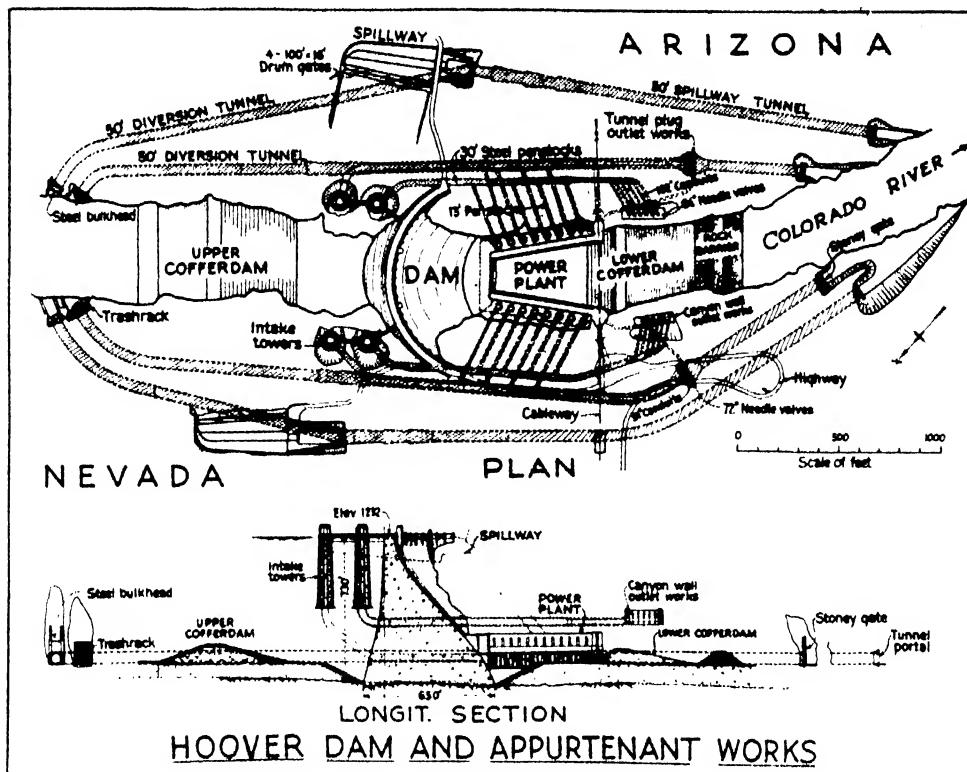


FIG. 2.

sively that the computed arch action takes place in a massive arch-gravity dam of the type selected. (Fig. 3.)

The effect of internal temperature variation, shear, twist, flow under stress, Poisson's ratio, foundation and abutment deformation, radial cantilever sides, uplift pressure at the base, uplift pressure in the pores of the concrete,

earthquake shock, spreading of canyon walls due to reservoir water pressure, and similar phenomena, have been analyzed and determined. The magnitude and distribution of stresses in all parts of the foundation and abutments under all conditions of loading have also been determined. The effect of non-linear distribution of stress in all parts of the structure, in both arch and cantilever elements, has been evaluated. The stress conditions caused by the sub-cooling of the concrete during the hardening period, by pressure grouting of the construction joints and by other load conditions to be encountered during the construction period, have been investigated. These analyses and determinations have required extensive researches into the fundamental theories of mechanics and elasticity and into the complete field of stress analysis.

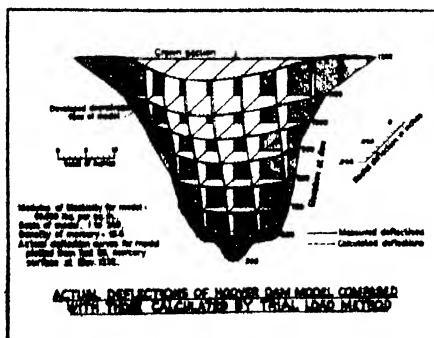


FIG. 3.

The original program of arch dam model testing that was started several years ago in cooperation with the Engineering Foundation Arch Dam Committee has been considerably extended in connection with Hoover Dam. It includes extensive research and investigations to determine the best and most suitable materials for use in models of this kind, including means of load application, and methods and technique in measuring and analyzing the resulting stresses and strains. The testing program included the building, testing and analyzing of a concrete model of the Stevenson Creek test dam, a concrete model of the Gibson Dam and a plaster of Paris and celite model of Hoover Dam. It also includes the construction and testing of a soft rubber model of Hoover Dam.

While these tests and analyses have not as yet been completed in all respects, the results so far accomplished have conclusively shown that arch action will take place as computed, and that the adopted design and dimensions of the dam are economical, adequate and entirely safe for all conditions of loading to be met.

Cement and Concrete Research: The science and art of concrete design and construction has received a great amount of study by many able scientists and investigators during the past two decades, and much progress and many improvements have been made. These studies have, however, been largely confined to ordinary concrete construction in which the maximum size of aggregate is about $1\frac{1}{2}$ inches in diameter. Massive concrete in large dam construction, where the dimensions of the concrete structure are of the order of several hundred feet, and where the aggregate varies in size from fine sand to cobbles as much as nine inches in diameter, presents problems in design and construction that have not heretofore been

satisfactorily solved. The results of past research in concrete, while valuable, and applicable in varying degree to all concrete work, do not furnish adequate data for the solution of these new problems. Although many concrete dams have been built regardless of the lack of complete data, the unprecedented magnitude of Hoover Dam and the requirement for absolute safety and permanence in this monumental structure make the solution of these mass concrete problems correspondingly more important than in any dam heretofore constructed. These problems must be thoroughly investigated and any fundamental data, now lacking, that are required for their solution must be secured, which is the main purpose of the program of concrete research.

The major portion of the concrete research program relates to the phenomena of heat generation in concrete during the hardening period, which are the cause of volume changes in the concrete. The control of volume changes is of utmost importance in a massive concrete structure such as Hoover Dam, which will be subjected to enormous water loads, and whose mass must be continuous in order to provide not only for watertightness but also for the proper distribution of stresses throughout the structure. The law of heat dissipation or cooling of masses is that the time required for cooling of similar shapes is proportional to the square of the dimensions. For instance, a concrete structure fifty feet thick will lose 90 per cent. of its temperature rise in one and one half years, whereas a structure five hundred feet thick will require one hundred and fifty years to lose the same proportion of its temperature rise. If Hoover Dam were built without control of the rate of placing and without special provision for cooling the concrete, the setting heat would probably not be dissipated for several hundred

years, during which time destructive volume changes would take place, resulting in undesirable and possibly dangerous open joints or cracks in the mass.

These conditions have necessitated two new and special provisions in the design of the dam: first, circumferential construction joints in addition to the usual radial contraction joints, thus dividing the mass into a series of approximately square columns or blocks; and, second, a complete artificial cooling system consisting of pipes embedded in the concrete through which cold water will be circulated. This system will lower the temperature of the concrete to normal and cause the resulting volume change to take place during the construction period, so that the joints between the columns, which will be opened as the concrete cools and contracts, may be completely and permanently filled with cement grout forced into place under pressure before the structure is placed in service.

In order that these problems may be intelligently studied and efficiently solved, extensive pioneer research pertaining to the thermal properties of cement and concrete is required. All properties of cement, both chemical and physical, must be exhaustively studied in order that a type of cement with controlled and known heat evolution may be specified. The researches into the properties of cement are being carried on under a cooperative agreement with the University of California at the Engineering Materials Laboratory of the University at Berkeley, where necessary special facilities and trained personnel are available for this work. The principal cement companies of Southern California are also cooperating generously in this work.

The cement investigations involve a study of 94 different cements, including tests on more than 15,000 specimens.

Of the cements being investigated, 28 are commercially ground; 22 are laboratory ground from commercial clinker; 20, covering an extreme range of chemical composition, are laboratory ground to equal fineness; and 24 are laboratory cements, laboratory ground to varying controlled degrees of fineness, from clinker of different chemical composition and different processes of clinker heat treatment. The investigation includes exhaustive studies of the effect of chemical composition; fineness of grinding; and, to a limited extent, the effect of manufacturing processes upon heat generation, volume changes, strength and durability. These cement studies are being supplemented, and will be concluded, in so far as Hoover Dam is concerned, by a series of tests on mass concrete now in progress at the Bureau of Reclamation laboratories in Denver, Colorado. Ultimately the three most promising cements will be further tested in the bureau's laboratories for temperature rise, volume changes and elastic and plastic properties. The studies thus far completed have indicated which of the cements tested have the most favorable characteristics and have made it possible to prepare and issue tentative specifications for the cement for Hoover Dam.

Researches being made into the thermal and related properties of concrete include the determination of the values of the thermal properties involved in the design of the cooling system; the practicability and efficiency of the cooling system as a whole; the determination of the rise of temperature that will take place in the interior of the dam; and the amount of heat that must be removed by the cooling system. Theoretical computations and laboratory tests are being supplemented by studies of the available records of heat development and volume changes in concrete dams previously built, and by specially

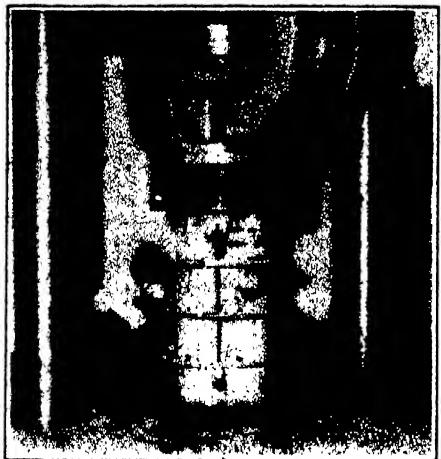


FIG. 4. TESTING 24" x 48" CONCRETE CYLINDER FOR MODULUS OF ELASTICITY AND POISSON'S RATIO IN 4,000,000 LB. CAPACITY HYDRAULIC TESTING MACHINE. DENVER LABORATORY.

planned field tests on the concrete in Owyhee Dam. These tests were started while the dam was under construction and will be continued throughout the cooling and pressure grouting periods.

Corresponding studies and researches are being made to determine the volume changes that will actually take place in the mass concrete of Hoover Dam. Concrete cores across contraction joints



FIG. 5. FAILURE OF 36" x 72" CONCRETE CYLINDER UNDER COMPRESSIVE LOAD. NOTE LINES OF CONICAL FRACTURE. DENVER LABORATORY.

have been drilled in the interior of Gibson Dam, from which the actual joint opening and the efficiency of the pressure grouting could be determined. Special instruments have been developed and installed in the mass concrete of Owyhee Dam to accurately measure the volume changes that take place. Large size laboratory tests are being conducted in Denver to determine the efficiency of pressure grouting in closing contraction joint openings in mass concrete and to determine the desirable size of the joint openings and the properties of the cement grout required for efficient grouting.

Other problems included in the concrete research program are tests of ultimate compressive strength; long time measurements of plastic flow under stress; determinations of modulus of elasticity and Poisson's ratio; tests of sliding friction, strength of bond at horizontal construction joints, comparative strength of test cylinders of different sizes, variation in strength with ages and curing temperatures, proper gradation of aggregates through a range of sizes up to cobbles nine inches in diameter, effect of vibration of fresh concrete and permeability of concrete.

The concrete research program has required the establishment of two large, adequately equipped laboratories in Denver. (Figs. 4, 5, 6.) Test specimens of concrete in great numbers, varying in size from three inches in diameter by six inches in length to 36 inches in diameter by 72 inches in length, are required to be manufactured and tested. A 4,000,000-pound hydraulic compression testing machine was purchased and installed for this work in cooperation with the Bureau of Standards. The successful development of the many new and ingenious instruments, and special fabricating and handling equipment, together with the technique necessary for carrying out these unprec-

edented tests, has been an important part of the work, but these details can not be described in the space allotted for this article.

Hydraulic Research: In the design and construction of its irrigation works, the bureau has on many occasions been confronted with the need for more thorough research in the field of hydraulics, and it has contributed in every way possible to the sum total of the knowledge now available in this branch of engineering science. During recent years the bureau has carried on a series of hydraulic model tests at the hydraulic laboratory of the Colorado Agricultural College at Fort Collins, Colorado. The data developed by these tests have proven valuable and conclusive in connection with the design of a number of outstanding hydraulic structures, including the spillways for Cle Elum Dam, under construction in the State of Washington, for Owyhee Dam in Oregon, and for Madden Dam in the Panama Canal Zone. The usefulness and indispensability of these and similar model tests in the efficient and economical design of large hydraulic structures, especially where unusual types or unprecedented dimensions and discharges are involved, have been fully demonstrated.

The enormous volumes of water that must be handled in the operation of Hoover Dam, together with the high heads involved, present extraordinary problems of design and construction. Hydraulic model testing is therefore being fully utilized in the design of the spillways and outlet works to supplement the theoretical hydraulic computations. The smaller scale model testing is being conducted in the Fort Collins laboratory. In so far as feasible, models of the same structure on two or more different scales are built and tested to better establish the similitude between the model tests and the performance of the prototype. A limited number of

relatively larger scale model tests, wherein the required dimensions and volume of water are beyond the facilities available at Fort Collins, are being conducted in a field laboratory established on the main canal of the Uncompahgre Project, near Montrose, Colorado. Tests to determine the resistance of concrete surfaces to erosion under high velocities were also made under simulated actual conditions at Guernsey Dam on the North Platte Project, near Guernsey, Wyoming.



FIG. 6. BATTERY OF INSTRUMENTS FOR AUTOMATICALLY CONTROLLING TEMPERATURES IN ADIABATIC CALORIMETER ROOMS. DENVER LABORATORY.

Hoover Dam is being built in a relatively narrow boxlike canyon with solid rock walls rising nearly vertically to the top of the dam and steeply for several hundred feet above. The hydro-electric power plant must be placed in the bottom of the canyon immediately below the dam, and will extend across the downstream toe of the dam and along the foot of the canyon wall on each side of the river for about 600 feet. The spillways will provide for a maximum

flood discharge of 400,000 second-feet. These conditions, together with the great height of the dam, dictated the adoption of spillways discharging through inclined tunnels excavated in the canyon walls rather than the more common types, where the water discharges over the dam or through separate open channels.

Two spillways of similar design, each with a designed capacity of 200,000 second-feet, will be provided, one being placed in the canyon wall at each end of the dam. The crest structure will consist of an overflow weir parallel to the canyon wall and controlled by four automatic floating drum type steel gates, each 100 feet long by 18 feet high. The water will discharge over the crest into a parallel channel excavated in the canyon wall and then turn at right angles to enter a steeply inclined funnel-shaped tunnel whose diameter decreases gradually to 50 feet. Each inclined spillway tunnel connects at river level with one of the 50-foot horizontal tunnels used for river diversion purposes during the construction of the dam, and the water will be discharged through these tunnels into the river about 2,000 feet downstream from the dam. When discharging at the designed capacity, the energy of the water that will pass through the spillways falling nearly 600 feet will be equivalent to approximately 22,000,000 horsepower and the water will attain a velocity of about 175 feet per second or 120 miles per hour. The dissipation of this tremendous energy without destructive effects has presented problems calling for thorough study and research.

Numerous variations in the details and proportions of the crest structure, gates, open channel and inclined funnel-shaped tunnels were considered and models of each proposed plan were constructed and tested before the most satisfactory design could be determined. These model tests have disclosed many condi-

tions of flow that could not otherwise have been foreseen or provided for, and have shown conclusively that present analytical hydraulic design methods are not adequate or sufficiently developed to be depended upon solely for the economic design of such unprecedented structures. Designs which would provide safe and satisfactory flow conditions could not have been developed without model tests, which have furthermore resulted in large savings in the cost of the spillway structures. (Figs. 7, 8, 9.)

A comprehensive series of tests was made to determine the erosive effect of high velocities of water on the concrete surfaces of the spillway tunnels. Concrete blocks with various surface characteristics were cast and subjected to the continuous action of a stream of water issuing from a one-inch nozzle at velocities ranging from 100 to 175 feet per second, and inclined at various angles to the surfaces under test. These tests were continued under fixed conditions and on individual blocks for periods of as much as 34 days, and the results demonstrated the feasibility of constructing concrete surfaces capable of satisfactorily resisting erosion due to flow of water under the required velocities but emphasized the importance in this connection of good alignment and smooth surfaces. The flow of water under high velocities over the concrete surfaces of the spillway tunnels will be intermittent, and seldom, if ever, continued over more than a few days in any year.

The outlet works for Hoover Dam, which will control the flow of water to the hydraulic turbines of the power plant and to the outlet valves, will include four vertical intake towers, each about 390 feet high and 82 feet in diameter at the base. Each tower will be provided with two sets of openings served by steel cylinder gates 32 feet

in diameter, which will control the flow of water into the outlet conduits. One of these sets of openings will be at the base of each tower and one at about mid-height.

A model of these intake towers to a scale of 1:64 was constructed and tested to investigate the hydraulic flow conditions and to determine the shape and proportions of the openings to minimize losses of head. These tests led to important improvements in the hydraulic design and also established the fact that an extensive air vent system which had been included as a feature of the design was unnecessary, thus effecting a large saving in cost.

The outlet pipes and penstocks will be of welded plate-steel construction of un-



FIG. 7. MODEL OF ONE OF THE TWO SPILLWAYS OF THE HOOVER DAM, ONE TWENTIETH ACTUAL SIZE. FLOW CORRESPONDING TO 120,000 CUBIC FEET PER SECOND. MONTROSE HYDRAULIC LABORATORY.

precedented size, arranged in four similar systems and installed in tunnels in the canyon walls on each side of the dam. Each system will consist of a main header, 30 feet in diameter, leading from the base of its intake tower and branching to four 13-foot diameter penstocks serving the hydraulic turbines. Downstream from the penstock branches the headers will be reduced to 25 feet in diameter and each of these headers will again branch to six conduits serving the outlet valves. The maximum discharge of each of the four systems will be about 33,500 second-feet which will require a velocity of



FIG. 8. FLOW IN MODEL OF HOOVER DAM SPILLWAY CORRESPONDING TO 120,000 CUBIC FEET PER SECOND. MONTROSE HYDRAULIC LABORATORY.

flow in the 30-foot headers of about 47.5 feet per second. Under the most severe conditions as to water-hammer, the conduits will operate under internal water pressures of about 300 pounds per square inch. To determine the pressure rise due to water-hammer under the given conditions required extensive original research and the development of formulae from the fundamentals of the mathematics involved.

A model of one of the systems was made, including model of the gate tower, and the hydraulic losses and flow conditions were ascertained by means of pressure measurements. These model tests indicated somewhat smaller head losses than were calculated from the tests made by Dr.-Ing. Professor D. Thoma at the Hydraulic Institute of the Technischen Hochschule, München, Germany. A transparent model of one branch connection was made and tested visually for flow conditions.



FIG. 9. THE APPEARANCE OF THE MODEL SPILLWAY FLOWING AT FULL CAPACITY, CORRESPONDING TO 200,000 CUBIC FEET PER SECOND. MONTROSE HYDRAULIC LABORATORY.

Discharges from the reservoir for uses other than electrical power development will be controlled by large balanced needle valves. On each side of the river there will be six 84-inch diameter valves discharging into the open from a valve house on the canyon wall, and six 72-inch diameter valves discharging into one of the 50-foot diameter diversion tunnels a considerable distance from its downstream end. These latter valves are arranged to discharge into the confined tunnels in order to effect a large economy in the length of the outlet pipes and also to provide a substantial part of the outlet capacity which can be operated without creating objectionable spray conditions adjacent to the power plant where many high-voltage conductors will be installed.

The correct arrangement of the six valves discharging into each tunnel is of great importance in order to avoid objectionable conditions from the standpoint of flow and erosion of concrete. This problem could only be solved by model testing. Accordingly, models were made and tested of the valve settings and tunnels to scales of 1:106 and 1:20. The arrangement of the valve discharges were varied in these model tests to determine the arrangement giving the best flow conditions. The results obtained from the two different scale models were similar and indicated satisfactory similitude between the models. These tests also demonstrated that certain provisions previously planned for introducing air into the tunnels below the valves were unnecessary and thus resulted in a material saving in construction cost.

Outlet Pipe Design: The design of the outlet pipe and penstock systems to meet the required conditions presents many unusual problems. No precedent exists for handling the quantities of water involved under such high pressures. The available space between the

canyon walls is too limited to permit the passing of the pipes and penstocks directly through the dam to the outlet valves and turbines, thus requiring them to be carried in tunnels in the canyon walls. The first plan tentatively adopted was to carry the water in concrete-lined pressure tunnels, but after careful studies of the stresses that would be developed in the rock of the canyon walls and consideration of the probable results thereof, the conclusion was reached that this would not be safe construction. The mathematical studies show that zones in the rock surrounding the pressure tunnels would be subjected to high tensile stresses and that any fractures of the concrete lining and the surrounding rock would permit dangerous leakage under high pressure into the surrounding rock areas. Other studies show that it is not economically feasible to make the concrete-lined tunnels positively watertight by steel reinforcement in the concrete or by placing continuous welded-steel lining against the inner surface of the concrete lining. Either method would require more steel than the adopted plan of constructing the 30-foot diameter pipes with sufficient plate thicknesses to support the full hydrostatic pressures. This plan insures full strength and watertightness and has the further important advantage of providing space in the tunnels surrounding the pressure pipes adequate for inspection and maintenance purposes.

Many of the problems involved in the structural design, manufacture and installation of these exceptionally large pipes inside of the tunnels in this remote and difficult location are new and unusual. The problems of design are intimately related to those of manufacture and installation, and the specifications for the pipe left many of the details of design, manufacture and installation for determination by the con-

tractor, subject to the approval of the contracting officer. The contractor for furnishing and installing the pipe, The Babcock and Wilcox Company, is carrying on a comprehensive program of research, including extensive testing of small and full-scale models to destruction for the determination of stresses and the details of design. The engineers of the bureau are cooperating in this program and supplementing it with other required model tests and much analytical research. These tests and analyses are disclosing many previously unknown elements in the design of such unprecedented pipe systems, and have shown that without this research program it would have been impossible to have prepared adequate and economical designs and manufacturing processes. Estimates at this time indicate that a large saving in cost of the steel pipe will be directly creditable to the research program.

Conclusions: Nearly all features of Hoover Dam and appurtenant structures require research work to aid in securing adequate and efficient design and construction. In almost every part of the work the dimensions, forces or condi-

tions encountered are unprecedented, and former theories and practises for work of this nature must be proven and tested as to their applicability to these unusual conditions and also supplemented with new procedures which must be developed and proven. Research, investigation and testing in many phases of design and construction are therefore necessary, and this brief outline of the work undertaken is far from complete. The results accomplished have been gratifying in the extent to which they have solved the problems which have arisen and have confirmed and supplemented previous theory and practise. The new knowledge obtained will be of great value in connection with future work of similar or greater magnitude. Thus far an estimated total saving in the construction cost of the Hoover Dam and appurtenant works of over two million dollars can be directly credited to the research program. The total cost of the program will be only a fraction of this saving, and the new knowledge developed thereby will be available without cost for use in solving similar engineering problems in the future.

RESEARCH IN THE BUREAU OF CHEMISTRY AND SOILS

By Dr. H. G. KNIGHT

CHIEF OF BUREAU, UNITED STATES DEPARTMENT OF AGRICULTURE

A PRINCIPAL object of the work of the Bureau of Chemistry and Soils is to increase the financial return to farmers by: (1) Solving certain technical problems which now stand in the way of greater or more profitable use of farm products, thereby expanding markets; (2) by more discriminating selection of soils for specific crops, the reduction of costs of fertilizers, increasing their efficiency and developing more suitable methods of application, thereby reducing unit cost of production of crops; (3) by reducing capital losses resulting from farm fires and soil erosion. These three factors concern the three fundamental elements in any industry, *i.e.*, (1) price and market for products; (2) cost of production; (3) conservation of capital.

The problems of agriculture vary from one era to another. Scientific programs of work in behalf of agriculture at the present time must take into serious consideration the present excess supply of many farm commodities and their ruinously low prices. This bureau's program has been designed to meet specifically some of the important present problems of agriculture. The work does not necessarily result in increased production. It does increase the net return to the producer and, paradoxical as it may seem, may result in reduced cost of product to the consumer.

Much of the work in this program directly assists diversification on small farms by providing greater facilities for diversification, for instance, through discovery of new uses for minor crops, thereby making possible a material degree of expansion. It also increases the

profitableness of certain crops which are particularly suitable for production on small farms, for instance, by better adaptation to market preferences and by profitable utilization of surplus and wastes. Also, as a result of new methods of utilization of farm wastes and surplus, new industries are created. This not only benefits agriculture by providing a market for otherwise unutilized products, but also provides employment for labor and profitable use for capital, thus benefiting the community as a whole. Furthermore, most of such products will be used for industrial purposes. They are not so perishable as most of the staple farm food products and hence could be marketed over a longer period. This, together with the resulting increased diversification of farm products, would increase the stability of farm income.

The apple is one of the foremost commercial fruits. The United States produces more apples than any other country in the world and is the source of the largest proportion of apples entering world trade. Without the use of insecticides to control insect pests it would be impossible to produce apples on a commercial scale, and without the use of chemical washing solutions to remove arsenical spray residues it would not be possible to market apples in the United States and foreign countries, where stringent regulations concerning permissible quantities of arsenical residues on apples are enforced.

The combination of salt and hydrochloric acid originated by the bureau has attained wide-spread use for the removal of lead arsenate residues from apples



SHOWING IN A SMALL WAY

IN AN EXPERIMENTAL BUILDING WHAT MAY HAPPEN ON A LARGE SCALE IN ANY DUSTY INDUSTRY
PLANT THAT IS NOT PROPERLY VENTED.

and pears. The use of new fluorine compounds has been recommended to replace lead arsenate and other arsenical sprays in order to eliminate or decrease lead arsenate residues on harvested fruits.

New insecticides, such as rotenone, neonicotine and new fluorine compounds, have been developed. Tests indicate that it may not be necessary to remove residues of sprayed rotenone from apples, in which case the cost of washing apples, amounting to not less than \$300,000 annually in the Wenatchee district of Washington alone, would be eliminated.

Two chemical substances have been separated from the wax-like coating of apple skins. About 500,000 pounds of each of these two substances can be recovered annually from apple pomace and peels which are now wasted in the production of cider and vinegar and in

dehydration of apples. Commercial uses for these substances in lacquers, varnish removers and dry-type stencils have been found, and commercial production is being undertaken.

The development of maturity standards which have stabilized materially the fresh-fruit market have resulted in an estimated increased value for citrus fruit of at least 35 cents per box during the first five years the standards have been in force. Much sound, mature citrus fruit is unsalable because the color does not meet consumers' preferences. Development of the ethylene gas treatment for hastening the development of color, according to estimates of leaders of the Florida citrus industry, added approximately 50 cents to the market value of each box so treated during the 1930-31 season. This amounts to an increase in value of the Florida orange



FRESH EXPOSURE OF SOIL.

NEW ROAD CUTS AND DITCHES ARE ALWAYS WELCOMED BY THE SOIL SURVEY MAN AS HE CAN FROM THESE OBTAIN THE BEST POSSIBLE IDEA OF THE SURFACE SOIL, SUBSURFACE AND SUBSOIL, AND UNDERLYING STRATA, AND ALSO THE COLOR, TEXTURE AND STRUCTURE OF THESE. HERE IS AN EXCELLENT EXAMPLE OF TRACING ARABLE AND PRODUCTIVE SOIL THROUGH ITS SUCCESSIVE STAGES OF FORMATION DOWN TO THE HARD ROCK FROM WHICH IT IS DERIVED.

crop of at least \$4,000,000 in this one year.

The ethylene treatment for hastening coloration and reducing astringency has been extended to other fruits, such as pears, apricots and persimmons, thus increasing their value for canning or direct consumption. The citrus by-products industry of California, the most highly developed of its kind in the world, is based solely on research work by the bureau. It has to date yielded growers a total of some \$7,000,000 as a result of salvaging thousands of carloads of cull and surplus lemons and oranges.

Methods of extracting lemon and orange oils and of producing an odorless pectin have been developed. Until the establishment of the citrus by-products industry in California, Italy was the chief production center for citric acid

and citrates for the drug and beverage markets of the world. Our domestic industry has not only displaced most of these products from Italy, but shipments of both citric acid and citrates are being exported. Our citrates have now displaced Italy's from the leading position in the British import trade.

Canning and preserving of fruits and vegetables is the largest food industry of the United States and is represented in every state of the Union. An important problem of farmers who grow fruits and vegetables for commercial canning is the increasing competition of fresh fruits and vegetables. Extension of truck growing in the Gulf coast region, together with improved transportation and refrigeration facilities, has made certain of the most common vegetables, such as peas, string beans and tomatoes, avail-

able in fresh condition throughout the year.

The increased availability of fresh vegetables during the off season has the effect competitively of raising the standard of quality which the consumer applies to canned products. Northern canners and growers of vegetables for canning are definitely confronted with the problem of retaining more completely the original color and flavor of these products when canned. Research by the bureau has yielded an improved method of canning, which, when applied to some commodities, produces goods of superior flavor. The flavor of products such as peas and sweet corn, when packed by this method, resembles closely those of the fresh products after cooking.

The United States is the principal world source of naval stores (turpentine, rosin, pine oil, and related products derived from the pine tree) and produces about 65 per cent. of the world supply. The average domestic production for the past three years has been about 35,000,000 gallons of turpentine spirits and 2,350,000 barrels of rosin. The total value (1929 Census Report) was about \$42,000,000.

An improved method of collecting pine gum to replace the wasteful and harmful practise of cutting a hole or "box" in the base of the tree has been devised. Improvements have been made in methods of distillation, still equipment and accessories used, and in the construction or "setting" of turpentine stills. Methods of testing naval stores have been outlined so as to provide suitable specifications for purchase.

The domestic sugarcane industry would profit from greater diversification of marketable products which would tend to stabilize the market and enable the industry to take fuller advantage of its contiguity to domestic consumers. A new product, "cane cream," and an im-

proved type of "la cuite" (exceptionally thick cane sirup) have been developed. Suitable methods have been indicated for producing on the plantation special grades of molasses and brown sugars which are in demand for specific purposes by certain industries, and the sale of which would yield an increased net return per ton of cane.

The bureau has shown the possibility of utilizing the residual fiber (bagasse) of sugarcane as a raw material for rayon through the production of a satisfactory grade of cellulose. Rayon at present is almost entirely made from cotton linters and wood pulp, but the supply of cotton linters soon will not be large enough to meet the demand. Cellulose made from sugarcane bagasse is superior to wood pulp cellulose as a base for rayon.

The production of the chemical compound, phthalicanhydride, by the bureau is a discovery upon which is founded the vat-dye industry in this country. With a few exceptions vat dyes are the only dyes applicable to cotton which are very fast to light and washing. Since these dyes are applicable to cotton, the latter is being used in an ever-increasing number of applications which formerly were not developed because the cotton could not be permanently dyed, and hence did not find uses in which fastness of color was essential. This discovery has also increased the number of dyes and the variety of colors which can be applied to cotton goods, thus adding to their attractiveness. Examples of the effectiveness of these dies in stimulating use of cotton goods are women's dresses and cotton drapes.

The bureau has developed a process for producing the chemical "furfural," the industrial production of which has increased from nothing in previous years to more than 1,000,000 pounds in 1929, with consequent utilization in that year of 5,000,000 pounds of oat hulls which



CORN-COB PRODUCTS

DR. W. W. SKINNER EXHIBITS A BLOCK OF HEAT-INSULATING MATERIAL, SOME SKEINS OF RAYON DYED WITH COLORS MADE FROM LIGNIN OF THE CORN-COB, AND OTHER ARTICLES PREPARED FROM CORN-COBS, NOW ALMOST ENTIRELY A WASTE PRODUCT.

would otherwise have been useless. Furfural is used chiefly in the manufacture of resins (for production of molded articles), as a solvent, and in the purification of wood rosin.

In the production of the great staple crops—the small grains, cotton, and sugarcane—there necessarily is grown an equal and usually greater tonnage of straws, stalks and bagasse (sugarcane residue) for which on the whole there is no adequate use. Relatively small amounts are now used as roughage, bedding or as fuel (sugarcane residue) and in maintaining the fertility of the farm. A comparatively small percentage is sold for industrial uses, such as production of paper and building boards.

A comprehensive investigation of the possibilities of using these various waste materials for a great variety of purposes is being made. Attention is being directed, for instance, to the destructive distillation of these wastes and the production of various products, including activated charcoal, carbon black for painting purposes, oils and tars for waterproofing and roofing materials, fuel

gas, so-called "dry ice," and numerous other products. A study is also being made of fermentation products, including fuel gas and the recovery of cellulose, fiber and other constituents, the thought here being that perhaps small towns, and even individual farm gas plants, may offer a worth-while outlet for these by-products, especially in those sections of the country where wood, coal and natural gas are not in plentiful supply locally.

The solution of these various problems of profitable utilization of agricultural wastes involves a subject of great magnitude. The stakes involved are tremendous, and a practical solution of the problem may be expected to increase farm incomes substantially.

It has been estimated that there are 1,400,000 people in the United States with diabetes or distinct diabetic tendency.

There is evidence that inulin is less objectionable in the diet of diabetics than other carbohydrates and can be eaten more freely. The Bureau of Chemistry and Soils has devised a process for producing pure inulin from chicory roots at reasonable cost. Tests of its value are now being made by six prominent medical specialists on diabetes. If present favorable indications are confirmed, use of inulin as a major source of carbohydrate in the diet of diabetics and persons with diabetic tendency would open up a large market for chicory. Chicory is at present a very minor crop, the acreage being about 3,900 acres (98 per cent. in Michigan), and the total return to farmers for the crop is about \$194,000. It is at present used only as a coffee substitute. In order to supply the possible demand from persons with diabetes, a total chicory acreage of 350,000 acres would be required, and the return from this at the present price of chicory would be about \$14,000,000. Work is now being done

on further reduction in the cost of inulin and on production of levulose sirup (as a by-product) of suitable quality to displace sirup made from imported cane-sugar.

Soil surveys enable the individual farmer to work out a cropping system that will permit the use of his soil resources to the best advantage. In the readjustment of cotton farming in the Southeastern states, as a result of boll weevil invasion, for example, a knowledge of the location and distribution of different soil types enabled the farmer to replace a part of cotton acreage with alfalfa. In the tobacco district such information has made it possible to select fields where the soil is capable of producing tobacco of the quality demanded by the market. In the extension of acreage of special crops in the West, soil surveys have been of great value in the avoidance of areas where the accumulation of salts and the development of alkali is a menace. In the development of reclamation projects a knowledge of soil types makes possible the avoidance of the costly mistakes which would result from carrying waters to lands not suited to agricultural development. Soil surveys are coming into ever-increasing use, as in land appraisal, the evaluation of lands in improvement of national parks, classification and allotment of Indian lands, etc. This work is being carried forward under definite plans already outlined.

Loss of soil fertility by erosion represents an annual loss which is undermining both the capital investment and the earnings of farmers throughout the whole United States. Therefore, conservation of soil resources is one of our most important agricultural problems.

More than 21,000,000 acres of land formerly under cultivation have been rendered essentially useless by gullying, and the impoverishing effects of sheet erosion are even greater. This erosive

process, which occurs during every heavy rain, is gradually whittling away the productivity of 75 per cent. of the crop land of the United States. No other nation in history has ever permitted its agricultural lands to deteriorate in this manner. Many thousands of farmers are trying to make a living on erosion-pauperized land where there is little opportunity for success even when prices are good.

Improved varieties of crops, increased use of fertilizer and labor-saving machinery, and the abandonment of worn-out land for land still retaining a part of the original top-soil have contributed toward maintenance of yields. In spite of these advantageous factors and the vast amount of effort devoted to better cultivation and rotation of crops, however, the yield per acre of corn has not increased and that of cotton has markedly decreased. Good land is largely under cultivation, but acreage is being constantly reduced by unrestrained erosion. With many farmers the evil of erosion-impoverished land is not a threat of the future; it is a present handicap which makes it impossible to gain a respectable living from the soil.

Investigation is being made of the erosion processes and their control by various methods, as well as of water con-



CELLULOSE FROM SUGARCANE

D. F. J. LYNCH HAS DEVELOPED A METHOD FOR
MAKING HIGH-GRADE CELLULOSE FROM BAGASSE,
THE WASTE FROM SUGARCANE.



A SOURCE OF CALCIUM SALT

H. T. HERRICK, CHEMIST IN CHARGE OF FARM WASTE INVESTIGATIONS, EXAMINES THE MOLD GROWTH ON A PAN OF GLUCOSE SOLUTION. THIS MOLD IS FORMING GLUCONIC ACID, WHICH IS USED IN MAKING AN EXPENSIVE CALCIUM SALT WITH HIGHLY IMPORTANT MEDICINAL PROPERTIES.

servation. Terracing experiments are being made to determine the best and most economical type for different regions. Strip cropping is being tested on both plot and field scale basis. Strips of thick-growing, soil-saving crops, such as oats, sorghum and sweet clover, are sown along the contours of slopes, and broader strips of clean-tilled crops, such as cotton and corn, are planted between. The thick-growing crops slow down the rate of run-off and cause much of the soil carried in flowing water to be deposited along these strips.

In regions of deficient rainfall good results have been obtained by the building of level terraces and by conducting water from sloping areas out over lower-lying areas through a system of embankments that distributes the water, holds it on the land and permits it to soak into the ground for future use.

A machine has been developed which digs 10,000 holes per acre on fallow

land; each excavation has a capacity of about five gallons. This scarification process, which can be done as cheaply as ordinary cultivation, holds back approximately 50,000 gallons of rain water per acre; thus absorption of water is greatly increased and erosion reduced. Investigation is being made of the rate of water run-off and the loss of soil on various slopes subjected to different cropping treatments. The relative rates of erosion of different types of fallow land, stubble land and land planted to various crops are being investigated.

While it is possible for the farmer for a brief period of time to reduce the scale of fertilizer application as an economy measure, this can be continued for only a short period before the fertility of the soil has been so reduced that profitable agriculture is no longer possible. It is the more essential that fertilizer use be continued if agriculture is to be lifted out of its present depression. It has been abundantly shown by scientific experimentation with fertilizers that through their use the cost of production can be materially reduced; in other words, that money spent for artificial fertilizers is returned with enhanced profits. This is particularly true during the present period of reduced prices for farm products. This fundamental fact is recognized by the farmer as evidenced by his continuing use of fertilizers even during the present period of economic distress. Fertilizer consumption has dropped about 50 per cent. under normal, whereas the consumption of other standard products, such as steel, has dropped 80 per cent.

The farmers of the United States normally use from seven to eight million tons of commercial fertilizer annually at a cost of approximately \$250,000,000. In certain states fertilizer is the farmer's largest item of expense, as, for instance, in South Carolina, where this cost amounted to 18 per cent. of the value of all crops grown in the year 1928.

North Carolina leads with an annual consumption that did not fall below a million tons for many years preceding 1932. It is in the South and East, where conditions make it difficult to maintain soil fertility, that commercial fertilizer has assumed its greatest importance.

It is the purpose of the fertilizer researches of the Bureau of Chemistry and Soils to enhance the economies of fertilizer use through lowering their cost to the farmer, through improving their qualities, through developing improved methods of application in the field, and through adjusting fertilizers to specific soil and plant requirements.

Accomplishments in which the bureau has shared include the following: Nitrogen fixation has been established in this country and a dependable supply of nitrogenous fertilizer assured at greatly reduced cost, the savings amounting to \$115,000,000 during the period 1924-1930; domestic sources of potash have been found and have already reached such a stage of development as to insure us against shortage or exorbitant prices, and savings of \$89,000,000 for the last 10 years on potash costs over what would otherwise have been spent are attributed to this research program. This country has been thoroughly aroused to the advantages of more concentrated fertilizers and the average percentage of plant food has gone up year by year until the estimated annual saving on bags, handling and freight amounts to \$15,000,-000; a good start has been made toward correct distribution in the field.

Chile can no longer dictate what we shall pay for nitrates. Nitrogen prices have dropped consistently since 1925. The saving to the farmer in the cost of the nitrogen content of his fertilizer over a 7-year period between 1924 and 1930 is about \$115,000,000. In the bureau's nitrogen research program the policy has been to work out fundamentals for the use of the industry.

Another important problem is to learn how the soil bacteria accomplish so much in the way of nitrogen fixation. The quantity of nitrogen lost annually from each cultivated acre in the United States through crop removal and as a result of leaching and volatilization is on the average about 40 to 50 pounds. The soil organisms replace a considerable part of this. The problem is to find out how these organisms accomplish so much without any of the elaborate equipment so necessary to our fixation processes.

The investigations dealing with the fixation of nitrogen by bacteria are yielding two types of results: (1) They are furnishing data regarding the chemical steps involved in nitrogen fixation in nature which should later serve as a basis for cheaper nitrogen fixation methods producing organic nitrogenous fertilizers—the form in most demand by the farmer, and (2) they are yielding information of direct value to the farmer which will enable him to improve his farm practises so as to make better use of nature's fixation methods and thus



DISTILLATION APPARATUS
J. O. REED, A CHEMICAL ENGINEER, WITH THE
STEAM TURPENTINE DISTILLER HE DEVELOPED.



TESTING AN INSECTICIDE

C. M. SMITH SWALLOWS A CAPSULE OF ROTENONE, A PROMISING NEW INSECTICIDE, SHOWN BY EXTENSIVE TESTS IN THE INSECTICIDE LABORATORIES TO BE DEADLY TO INSECTS, BUT HARMLESS TO MAN.

partially eliminate the need for the purchase of commercial fertilizer nitrogen.

Potash researches were inaugurated at a time when the American farmer was wholly dependent on a foreign monopoly for all of that fertilizer essential. Importations were at the rate of 1,000,000 tons of potash salts annually and a cost of \$25,000,000. The objective was the development of a domestic industry, to render America independent, to establish competition to maintain prices on a low competitive level, and to reduce costs through shortening freight hauls from producing centers to the farms where used. Great success has attended these efforts with marked savings currently accruing, which will increase as the benefits of past and present technological researches are realized.

Potash-producing units of large capacities now established in this country

unfortunately are still for the most part remote from agricultural areas where the bulk of fertilizer potash is used. The 1930 freight bill of \$6,500,000 on the potash salts paid by the farmer remains to be reduced through the establishment of additional production units closer to these areas and further increases in concentration of salts transportable at proportionately lower rates. Despite progress to date, payments to Europe for fertilizer potash are still being made at the rate of \$12,000,000 annually. The vast deposits of potash silicates, widely distributed, are still unexploited; much by-product potash is still lost to industry. Recent technological developments, for which this bureau is responsible, show how these resources may be placed at the service of agriculture at prices reducible in terms of both production and distribution costs.

As one instance is cited the concurrent smelting of potash and phosphate rocks to produce potassium phosphate, a double fertilizer salt of 100 per cent.



POSTMEN COOPERATED WITH LEATHER CHEMISTS

MAKING STUDIES TO DETERMINE THE EFFECT OF DIFFERENT KINDS OF TANNING ON THE WEARING QUALITIES OF SOLE LEATHER.

concentration susceptible of wide distribution, and bringing into production the vast fertilizer resources of certain Rocky Mountain States with production costs that definitely promise the establishment of profitable industries, with products entering foreign competition both at home and abroad.

The United States is well supplied with phosphate rock and sulfuric acid required for superphosphate production, having long been an exporter of the rock as shown by the production and export figures.

The problems of the phosphate industry center around the conservation of the phosphate rock supply and the production of more concentrated phosphate fertilizers to cut down freight in accordance with the trend of the fertilizer industry in that direction. The present practise results in excessive waste at the mines in the form of tailings of too low grade for use in superphosphate production. Superphosphate carries only 16 to 20 per cent. plant food (P_2O_5), whereas products can be made having three times that concentration. Since superphosphate is a low-priced commodity, the cost of production being only \$6 per ton under favorable circumstances, the packing and freight charges make up an unusually large part of the ultimate cost to the consumer. In many cases transportation on raw materials to the factory and on the finished product to the point of consumption amount to more than half of the cost to the consumer.

Investigations now in progress have for their objective savings comparable to those already achieved in connection with the nitrogen supply. Conservation of the phosphate rock supply will also result.

A problem of far-reaching importance in soil fertility is that of maintaining the reaction of the soil at the proper level for maximum yields and best quality of the crop. Certain of the cheapest fertilizer materials now on the market have the property of increasing the acidity of the soil. Unless means are taken to prevent this a serious decrease in the crop-producing capacity of the soils of the United States is certain to result, as has already occurred in sections of other fertilizer-consuming countries. With a view to correcting this condition a study is now being made of methods for preparing fertilizer mixtures with such a balance of acid and basic components that the reaction of the soil to which they are applied will remain the same.

Increasing the efficiency of fertilizers by determining their proper placement in the soil with respect to the seed for maximum yields has also received a great deal of attention during the past 2 or 3 years. Best results are obtained for most crops when the fertilizer is applied in bands to the side of the seed. When this is done the simultaneous distribution of the fertilizer and seed may be made in safety and the expense of their separate distribution is avoided.



HUMPHRY DAVY

THE ILLUSTRATION SHOWS THE APPEARANCE OF HUMPHRY DAVY AT THE AGE OF TWENTY-THREE,
OR ABOUT TWO YEARS AFTER THE COMPLETION OF HIS EXPERIMENTS ON NITROUS OXIDE AND THE
NOXIOUS GASES.

HUMPHRY DAVY AND CARBON MONOXIDE POISONING

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"A SHORT time after I began the study of chemistry, in March 1798," wrote Humphry Davy in his book on nitrous oxide,¹ "my attention was directed to the dephlogisticated nitrous gas of Priestley, by Dr. Mitchill's Theory of Contagion." In a footnote thereto appended, it was explained that the New York physician, Samuel Latham Mitchill, had suggested that nitrous oxide, which he called oxide of septon, was responsible for the plague. The gas, when inhaled, was supposed to produce sudden death, and scarcely less terrible results when applied to the skin. "The fallacy of this theory," continued Davy, "was soon demonstrated by a few coarse experiments made on small quantities of the gas procured from zinc and diluted nitrous acid. Wounds were exposed to its action, and the bodies of animals were immersed in it without injury; and I breathed it mingled in small quantities with common air, without remarkable effects. An inability to procure it in sufficient quantities, prevented me at this time from pursuing the experiments to any greater extent. I communicated an account of them to Dr. Beddoes."

There is little doubt that these researches of the youthful poet and philosopher, together with other qualities described in detail by his biographers,^{2,3}

¹ The quotations herein are taken from John Davy's "The Collected Works of Sir Humphry Davy. Volume III. Researches, Chemical and Philosophical, Chiefly Concerning Nitrous Oxide, or Dephlogisticated Nitrous Air, and Its Respiration." London (1839). This monograph was first published in 1800.

² John Davy, "Memoirs of the Life of Sir

were largely instrumental in securing his first appointment. In 1798 Davy was released from an incompletely completed apprenticeship to Mr. Borlase, an apothecary-surgeon in his native town of Penzance, to assume the duties of laboratory director at the Medical Pneumatic Institution in Bristol. The necessary equipment was made available in the early part of 1799, from funds obtained through the efforts of Dr. Beddoes, for the study of the possible therapeutic value of various gases. Medical scientists, then as now, were eager to apply the latest discoveries in chemistry to the treatment of diseases. It was only natural that the study of the "factitious airs" should be undertaken. Carbon dioxide had been described by Black in 1757, hydrogen was isolated by Cavendish in 1766, oxygen by Priestley and Scheele in 1771, nitrogen by Rutherford in 1772 and, in the same year, nitrous oxide by Priestley. When Davy began his studies in the new laboratory at Bristol, the contributions of Lavoisier to the chemistry of respiration had been terminated by the execution of the founder of modern chemistry but five years before.

Within a comparatively short time, Davy had learned to prepare large quantities of nitrous oxide in pure form, had analyzed the gas with surprising accuracy, considering the limitations of his apparatus, and had showed its relationship to nitric oxide. The chemical

Humphry Davy, Bart." London (1836). Two volumes.

³ J. A. Paris, "The Life of Sir Humphry Davy," London, 1831.

Fig. 1.
VOL. I. p. 291 *Sublimation of Sulphur*

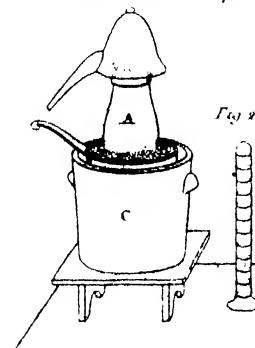


Fig. 3.
Decomposition of water by Carbon.

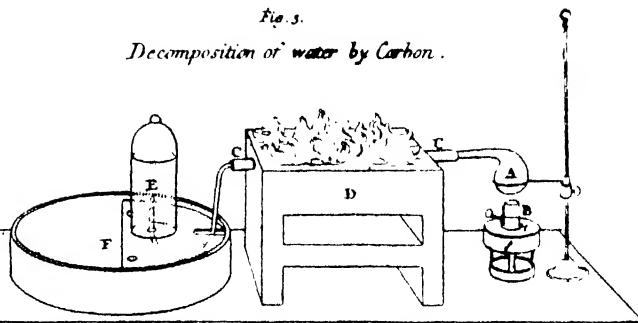


PLATE XI.

THE FIGURE FROM JANE MARCET'S "CONVERSATIONS ON CHEMISTRY," AMERICAN EDITION OF 1818, EDITED BY THOMAS COOPER, SHOWS THE TYPE OF APPARATUS ONCE USED TO PREPARE SMALL QUANTITIES OF WATER GAS. MRS. MARCET'S BOOK WAS BASED ON DAVY'S LECTURES AT THE ROYAL INSTITUTION IN LONDON, AND WAS RESPONSIBLE FOR INTERESTING MICHAEL FARADAY, AS A BOOK-BINDER'S APPRENTICE, IN THE SUBJECT OF CHEMISTRY.

aspect of the problem thus being placed on a firm basis, he turned his attention to the detailed study of the effects produced by breathing nitrous oxide. In the early experiments animals were used. They included dogs, cats, rabbits, guinea-pigs, mice, a hen, a goldfinch, "water lizards," two species of fish, butterflies, a drone, flies, snails and worms. The land animals were placed in atmospheres of nitrous oxide, the fish were immersed in water that had been saturated with the gas, and the "water lizards" were tried in both. Though the experiments on the animals yielded some interesting data, they were not considered satisfactory because, as Davy remarked, the animals all succumbed in about the same time in nitrous oxide as in those gases known to be incapable of supporting life. It was thereupon decided to make observations on himself. For present purposes we need not dwell upon the experiments on "laughing gas," as Davy's nitrous oxide came to be known, because they immediately attracted popular attention and because they are still counted among the commonly known anecdotes of the history of chemistry. In passing over these

familiar experiments, however, let us not forget the zeal with which Davy pursued his studies. We may carry with us, if we like, a mental picture of the young investigator on the day after Christmas in 1799, crouching in an air-filled box for an hour and fifteen minutes, feeling his pulse and recording his body temperature with a large bent thermometer placed under his arm, while assistants admitted more and more nitrous oxide into the chamber.

But among the less well-known investigations described in Davy's monograph are several of historical significance as early contributions to the study of respiration and the toxicology of the noxious gases. These experiments were performed by Davy on himself to compare the effects produced by nitrous oxide with those evoked by other gases. Nitrogen, hydrogen, carbon dioxide, nitric oxide and water gas were studied.

When breathed in small quantities, nitrogen and hydrogen produced only symptoms of suffocation; they were said to be inert because they did not produce the subjective excitement typical of partial anesthesia. Different results were

obtained with carbon dioxide. "It tasted strongly acid in the mouth and fauces," Davy said of the pure gas, "and produced a sense of burning at the top of the uvula. In vain I made powerful voluntary efforts to draw it into the windpipe; at the moment that the epiglottis was raised a little, a painful stimulation was induced, so as to close it spasmodically on the glottis; and thus in repeated trials I was prevented from taking a single particle of carbonic acid into my lungs." The same protective mechanism was set in action by air containing 60 per cent. carbon dioxide. When the concentration was reduced to 30 per cent., the mixture was respirable for short intervals. No marked effects were observed other than those due to deprivation of oxygen, unless the symptom of sleepiness that was also recorded is interpreted to mean the effects of the hyperpnea which is now known to be produced by carbon dioxide.

In a "fit of enthusiasm," an expression with which the modern reader will probably agree, Davy tried to breathe nitric oxide. This gas combines with the oxygen of moist air to form brown fumes of nitrogen dioxide and, to avoid this reaction, Davy breathed the gas after preliminary inhalation of nitrous oxide had removed most of the common air from his respiratory tract. The toxicity of the higher oxides of nitrogen is now known to be due to their action on the lungs. They dissolve in the cellular fluids of the lung tissue, forming acids and producing irritation and the slow accumulation of more or less fluid. In a severe case of poisoning the victim may die from edema of the lungs some hours after the immediate effects of the gas have worn off and the patient feels that he has recovered. Fortunately, as Davy realized when the experiment was abandoned, it was found impossible to draw the gas beyond the glottis. The fumes burned the mouth of the young

experimenter and made his teeth sensitive.

Although Davy was saved considerable discomfort, if not more serious consequences, from the acid-forming gases by the spasmotic closure of the glottis, this protective reflex was not elicited by another toxic gas that he studied. This was "hydrocarbonate." It is now known as water gas, because it is made by boiling water and passing the steam over heated charcoal. Although the main reaction can be written $H_2O + C = H_2 + CO$, showing that equal volumes of hydrogen and carbon monoxide are formed, small amounts of carbon dioxide and hydrocarbons are also produced, traces of oxygen and nitrogen are present, and the carbon monoxide content is usually not more than 40 per cent. The toxic properties are due to the carbon monoxide, although there is some evidence that commercial illuminating gases, such as coal gas, are somewhat more poisonous than their content of carbon monoxide would indicate. It was not until 1857 that it was proved, by Claude Bernard, that carbon monoxide is not a simple asphyxiant, but acts by forming a firm combination with the hemoglobin of the blood, and thus deprives the tissues of oxygen. Nevertheless, Davy stated that hydrocarbonate destroyed life "by producing some positive change in the blood, which probably immediately renders it incapable of supplying the nervous and muscular fibers with principles essential to sensibility and irritability." One need only explain that the essential principle is oxygen and, perhaps, add a few details concerning the decreased rate of transfer of oxygen from blood to tissues in carbon monoxide poisoning, and the statement is brought up to date.⁴ As is

⁴ A recent account of the anoxia of carbon monoxide poisoning is presented in the treatise of J. P. Peters and D. D. Van Slyke, "Quantitative Clinical Chemistry. Volume I. Interpretations." Williams and Wilkins Co., Baltimore. 1931.

indicated in the following account of his experiments, Davy was not the first to work with water gas inhalation, and the prophetic conclusion cited above was partly based on earlier contributions.

Mr. Watt's observations on the respiration of diluted hydrocarbonate by man, and Dr. Beddoes's experiments on the destruction of animals by pure hydrocarbonate, proved that its effects were highly deleterious.

As it destroyed life apparently by rendering the muscular fibre inirritable without producing any previous excitement, I was anxious to compare its sensible effects with those of nitrous oxide, which at this time I believed to destroy life by producing the highest possible excitement, ending in lesion of organization.

In the first experiment, I breathed for near a minute three quarts of hydrocarbonate mingled with nearly two quarts of atmospheric air. It produced a slight giddiness and pain in the head, and a momentary loss of voluntary power: my pulse was rendered much quicker and feebler. These effects, however, went off in five minutes, and I had no return of giddiness.

Emboldened by this trial, in which the feelings were not unlike those I experienced in the first experiments on nitrous oxide, I resolved to breathe pure hydrocarbonate.

For this purpose, I introduced into a silk bag four quarts of gas nearly pure, which was carefully produced from the decomposition of water by charcoal an hour before, and which had a very strong and disagreeable smell.

My friend, Mr. James Tobin, Jun. being present, after a forced exhaustion of my lungs, the nose being accurately closed, I made three inspirations and expirations of the hydrocarbonate. The first inspiration produced a sort of numbness and loss of feeling in the chest and about the pectoral muscles. After the second inspiration, I lost all power of perceiving external things, and had no distinct sensation except of a terrible oppression on the chest. During the third expiration, this feeling disappeared, I seemed sinking into annihilation, and had just power enough to drop the mouth-piece from my unclosed lips. A short interval must have passed during which I respired common air, before the objects around me were distinguishable. On recollecting myself, I faintly articulated, "I do not think I shall die." Putting my finger on the wrist, I found my pulse thread-like and beating with excessive quickness.

Davy's description of the symptoms of carbon monoxide poisoning is strik-

ingly similar to the more precise account by Haldane in 1895. By means of a rapid method for the quantitative estimation of the amount of the blood pigment combined with carbon monoxide, this distinguished English physiologist was able to correlate the symptoms with the degree of saturation of the blood. When one third of his blood pigment was combined with carbon monoxide, Haldane noted symptoms of discomfort when quietly resting, and complained of dizziness, palpitation and blurring of vision when the oxygen deficiency was accentuated by exercising. With the blood half saturated, even the resting subject was on the verge of collapse. From Davy's description it would appear that his blood was about half saturated with the gas. It may also be noted, in resuming the account, that the symptoms of asphyxiation became aggravated following exertion.

In less than a minute, I was able to walk, and the painful oppression on the chest directed me to the open air.

After making a few steps which carried me to the garden, my head became giddy, my knees trembled, and I had just sufficient voluntary power to throw myself on the grass. Here the painful feelings of the chest increased with such violence as to threaten suffocation. At this moment, I asked for some nitrous oxide. Mr. Dwyer brought me a mixture of oxygen and nitrous oxide. I breathed this for a minute, and believed myself relieved. In five minutes, the painful feelings began gradually to diminish. In an hour they had nearly disappeared, and I felt only excessive weakness and a slight swimming of the head. My voice was very feeble and indistinct. This was at two o'clock in the afternoon.

I afterwards walked slowly for about half an hour, with Mr. Tobin, Jun. and on my return, was so much stronger and better, as to believe that the effects of the gas had disappeared, though my pulse was 120, and very feeble. I continued without pain for near three quarters of an hour, when the giddiness returned with such violence as to oblige me to lie on the bed; it was accompanied with nausea, loss of memory, and deficient sensation. In about an hour and a half, the giddiness went off, and was succeeded by an excruciating pain in the forehead and between the eyes, with transient pains in the chest and extremities.

Toward night these affections gradually diminished. At ten, no disagreeable feeling except weakness remained. I slept sound, and awoke in the morning very feeble and very hungry. No recurrence of the symptoms took place, and I had nearly recovered my strength by the evening.

Since Davy's time it has been shown that carbon monoxide is a cumulative poison, its effects being dependent not only on the concentration in the inspired air, but also on the time of exposure and the rate of respiration. Henderson and Haggard⁵ have estimated that three parts of carbon monoxide in ten thousand is the maximum permissible in atmospheres to which men may be exposed for several hours. The gas is eliminated from the body in the form of the unchanged monoxide, and through the same channel as it enters, the lungs. Haldane found that the breathing of oxygen gas alleviated the symptoms of poisoning, but even after being able to move about normally, a violent headache, such as Davy described, persisted. This symptom is supposed to be caused by pressure in the brain that results from the edematous swelling that, in turn, is brought about by the anoxemia. The modern method of resuscitation was devised by Henderson and Haggard. It

⁵ Yandell Henderson and H. W. Haggard, "Noxious Gases and the Principles of Respiration Influencing Their Action," Chemical Catalog Company, New York. 1927.

consists in the administration of oxygen containing 5 per cent. carbon dioxide. The latter gas is the natural stimulant for respiration, its inclusion causing deeper breathing and bringing about the elimination of carbon monoxide in a much shorter time than is possible with oxygen alone. In the majority of subjects treated by this method of resuscitation, which is very effective provided it is begun before the heart has actually stopped beating, no after-effects are experienced. Even the severe frontal headache is often prevented.

To those familiar with the development of our knowledge of the toxic gases since 1800, when Davy's monograph first appeared, it is well known that much information has been derived through the medium of animal experimentation. Such knowledge has been supplemented from time to time by observations made on scientific men themselves or on the unfortunate victims of gas poisoning. A number of investigators have been injured or killed in the course of laboratory studies on respiration. Fortunately for the history of chemistry, Davy did not become a martyr to science and, as his brother has recorded, condemned the practice of self-experimentation in a letter to a medical student a few years after his almost disastrous experiences with the toxic gases.

PLAYING THE SCIENTIFIC GAME

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A DICTIONARY definition of science is to the effect that science is classified knowledge, or is knowledge gained and verified by exact observation and correct thinking, or is an exact and systematic statement of knowledge concerning some subject. The term scientist is defined as one versed in science or devoted to science. Actually, although the word science implies knowledge, the term is commonly used to mean research, and a more adequate definition of science would take cognizance of the business of acquiring new knowledge. The dictionary definition is, in effect, a teacher's definition of science as it is presented to undergraduate students. It does not express the meaning which investigators commonly attach to the word science, and in emphasizing our knowledge such definitions contribute to our delinquency in allowing students to escape from science courses without grasping one of the most important things science can teach us, which is the meagerness of our knowledge and the appalling extent of our ignorance. The meaning definitely attached to the word scientist by scientists is that of investigator. A teacher of science may or may not be a scientist, in the sense in which scientists use the word, just as a writer of detective stories may or may not be, and usually is not, a detective.

Whatever our definition of science, our actual concept of it is colored and flavored by our experience and temperament, and attempts to convey our concept to persons who have never hunted elusive facts and unknown things is usually not very successful. Some scientists regard research as an occupation

which occupies their working hours. Some regard it as something akin to a religious activity. Personally and at this time I prefer to regard it as a game which has a peculiar charm. Games are affairs of competition or of chance, and science is both a competitive match and a gamble. The scientist's generally recognized opponent is nature, and this dear antagonist numbers among her many charms that most precious of good qualities in gamesters—sportsmanship. For nature has shown in all her dealings with her human opponents that she plays the game fairly. The scientist has another opponent, the believer in magic, and this dark opponent, who is not so generally recognized, plays a more devious game.

Nature's habit of fair play commands the scientist's respect and admiration. The scientist undertakes to trick nature out of her secrets, to pry into her mysteries and to learn her laws, in order that when he has discovered those secrets, mysteries and laws, he may harness the forces of nature, render her deadly weapons harmless, and change her from a dread goddess to his slave. Mortal antagonists approached in such spirit and with such intent show little regard for such rules of the game as may be drawn up, or for fair play, but nature is quite sporting about it.

Our delightful opponent has arranged the game along these lines: We can come constantly closer in our approach to absolute knowledge, to ultimate things and to perfection, but we can attain none of these things. Nature agrees to observe the laws of cause and effect, operating in due sequence and with re-

sults proportional to cause. She will do nothing to stop our investigations except as we run afoul of her laws of cause and effect, and will wage on us no counter-war except as she has already laid on us her inhibitions by building into her human creation those things which constitute the nature of man. Because of those inhibitions, manifest in what is called "human nature," our other opponent, the belief in magic, is invoked against us and we become our own worst enemies.

The impossibility of our attaining perfection is one of the earmarks of nature's arrangement that stamps it as a perfect arrangement. It would be disconcerting to find that nature had set up this fine large universe in such shallow fashion that the inconsequential human animal, with his all too evident imperfections, could grasp some part of that universe in its entirety, and present to critical intellects the appalling spectacle of imperfection comprehending perfection. It would be a gloomy outlook if there were the likelihood that we might know everything, and thereby court eternal boredom. Finally, if the scientist could know everything about his subject, he would work himself out of a job, and ultimately have to turn to politics, law or writing, where the inexhaustible supply of words promises to furnish endless occupation unless humanity finally talks or reads itself to death. Fortunately, there is no threatened answer to Faust's question:

"Welch Schauspiel! Aber, ach! Ein Schauspiel nur!
Wo fass' ich dich, unendliche Natur!"

The dependability of nature's law of cause and effect makes science a real game of skill, as well as chance. It permits us to repeat our experiments with the certainty that nature, unlike human law-makers, will not pass new laws overnight, and that an acid will not turn

litmus pink one day and blue the next day. The principle of uncertainty has not upset our confidence that nature will play the game fairly and according to rules which we can formulate and on which we can depend. Nature does not play polities, she does not vote dry and drink wet, and she registers her vote on all subjects without diffidence, modesty or hypocrisy.

While nature will play the game fairly and dispassionately, she has from ancient times set up her defenses against the prying eyes and poking fingers of the scientist. One of her defenses is inherent in the intricate mechanism of the universe. The qualities of infinite vastness and infinite minuteness, of infinite variety in shape, color, sound and odor, of infinite varieties in speed, of endless reactions and interactions, and other complexities, ensure that nature will ultimately outwit finite minds.

But even more efficient is the opponent which nature has evolved in molding the mind of the man who seeks to solve her cryptic composition. In his long ascent to his present not too high station as an intelligent animal, man has constantly been under the lash of nature, and by many centuries of attack with famine and disease, with fang and claw, with volcano and earthquake, she has built into his soul fear and furtiveness and dishonesty. For thousands of years man has sought to placate the destroyer, and it is from a stuff into which a cringing soul is built that the mind of to-day's scientist must be shaped. This odd little product of nature, man, has for thousands of years looked with terror at his creator, and although he now looks at her with questions in his eyes, nature can look with smiling confidence into those questioning eyes. She has in good time taken steps to blunt the weapon which man now turns against her. For that weapon of research is the mind of the scientist, and that weapon she has

herself fashioned, as Excalibur was fashioned, with specific powers and quite adequate limitations. Who wields this weapon effectively must have the qualities of keenness, courage and honesty, and this requirement is a restraint which is put upon us. Keenness without courage, courage without honesty or honesty without keenness will not serve. Stupidity, cowardice and dishonesty alike are fatal to the scientist, for none of these serve Truth, and all of them serve the believers in magic.

A certain keenness is not lacking in man's mental make-up. Dodging saber-toothed tigers, stalking game, snaring fish, climbing trees and mountains, devising home and clothing from such parts of the scenery as lent themselves to such uses, and otherwise solving the urgent problems of self-defense and food could not fail to put an edge of some sort on the mind of man. The experimental method of trial and error had its beginning among ancient things, and the scientist needed only a somewhat new set of problems and some refinements in procedure to start him on his new career; keenness of intellect in some degree might be predicated of him with some assurance.

Of moral courage not quite so much could be expected. Our minds are still dominated by fear, fear of pain and hurt, fear of losing our living, fear of losing our reputation, fear of trouble and struggle. There is in science some antidote for fear, since science is the search for reality, and fears are mostly imagination, but the scientist remains human, and because he is human, he, too, courts unreality and delusion, and desires ease and comfort and certainty and approval and applause, and fears the loss of these things. There is in science a discipline that is to some extent a stiffener of courage, for many of our experiments show the poverty of our reasoning and bring to us a disappointment that

must either temper our courage or unfailingly breed discouragement. There is in science little of reward in material things, and courage may be expected to spring in minds which renounce the soft life. But science works no miracles in tempering metals that can not withstand the tempering fire.

As regards the quality of honesty, in the sense of intellectual honesty, one may expect substantially as little as of moral courage. For thousands of years man had lived by his wits. He had outwitted huge reptiles and mammals, but the result was a development of shrewdness rather than a balanced intelligence. There is a quality of trickiness about cleverness in combat and war. It breeds deceit and dishonesty rather than straight thinking.

And when man's tricks and deceits failed, he suspected nature of animistically taking sides in his affairs, and sought to appease and bribe her. Later he called upon his various gods to help him and to defeat his opponents. From such pious beginnings man has developed his second enemy, the belief in magic. For the essence of science is that nature's laws are observed, not part of the time or most of the time, but all the time, whereas the essence of magic is that nature's laws, like man's laws, are capable of being evaded, modified, suspended or vetoed. Mankind desires, and seems to expect, as a solution of most of its problems, something along the lines of a Gilbert and Sullivan opera. Somewhere, perhaps just around the corner of which we have heard so much, is a Little Buttercup waiting to admit that she "mixed them babies up," after which all will be well with "this best of all possible worlds." It is with genuine regret that we dismiss the expectation of the Gilbertian solution and of the delightful magic effects with which Cabell fulfills the desires of his heroes and heroines, for these things have the

merit and charm of artistry. However, it is only in such fields as law that the Gilbertian interpretations are taken seriously, and the Cabellian formula achieves highly impermanent results for its heroes and heroines. The only permanence achieved is that inherent in Gilbert's and Cabell's artistry. The scientist not only expects that science will have as much permanence as art, but that scientific thought and its benefits to mankind will last at least as long as that fragile and vulnerable race. Somewhat like Père Coignard, we may believe that such personal matters as religion and romance and art can be dealt with in a spirit of faith and emotion, but that communal affairs must ultimately be dealt with in a spirit of common sense and intelligence and facts.

It is not just the man on the street, the farmer in the dell and the savage in his jungle, who believe in magic. In one way or another, scientists in general believe in some fashion what they disbelieve in another fashion, that nature does not always play the game fairly and that she can be persuaded by appropriate supplications, incantations or ceremonies to suspend her laws of cause and effect, to skip the beats in her accustomed rhythm, to double-cross some one or something and to dispense special favors to the initiate and elect. Whether our belief in magic takes the form of a belief that the hex spell may be cast on an enemy, or disaster ensured by the lighting of three cigarettes with one match, or rheumatism cured by carrying a buckeye in our pocket, or economic troubles cleared away by voting the right ticket or sociologic problems solved by the passage of a law, is only the difference between black, white or gray magic. One way or another nature has set her limitations on our intellectual honesty, and there is no lack of scientists who make their data prove the conclusions they set out to prove or destroy

the specimen that does not fit into their classification. Intellectual honesty is difficult to achieve; one is tempted to say of man at this stage of his development that it is almost impossible to achieve. We have developed methods for our combat with nature. By what methods are we to combat magic? What are we to oppose to the abracadabras, exorcisms or cantraps of the magician?

Man does not enter the field of science as a scientist. He enters as a man and a novice, and many who work daily in laboratories and are called scientists never conclude the novitiate which endows them with the scientific mind, or, if they have achieved it, never take that mind out of the laboratory. We bring with us our established patterns of childish behavior and the sense of values inculcated in childhood. We have been told, and we have believed, that gold is good, that fame is admirable, and that assurance of ease is a worthy end in life. It is hard to unlearn these lessons, to pursue truth instead of profit, to look for facts instead of fame, to scan our specimens and our reactions and not the lists of degrees, awards and prizes, and to elect the life of work and reject the life of ease. Science dispels illusions, and it takes courage to withstand disillusion and still face smilingly and with a high heart a life of reality which eludes us and a certain death which overtakes us. Courage is not granted to all men, be they scientists or not, and the hobo and idle inheritor of wealth do not walk the path of social parasitism unaccompanied by what are called and generally believed to be scientists.

There is no magic in research. Scientific facts can be taught, and are taught. Research methods can be taught and would be taught better if we could disabuse our minds of the idea that there is some magic by virtue of which this man is a research worker and that man is not. It is not magic that makes the

investigator; it is the possession of intellectual keenness, courage and honesty, a capacity for applying these qualities to our work and to our life, and the ability to strengthen these qualities by constantly exercising them. On any basis of fact content of any sort, and in dealing with any subject-matter, the systematic application of these qualities in a search for new facts is research.

You will not think that I come here to criticize science or scientists before my "companions in zealous research." If this is no eulogy of science as it is manifested to our observation, it is at least an appreciation of what might be, and to some extent is, a search for truth, and is an appraisal of the difficulties and hazards of playing the scientific game. If it is no eulogy of all scientists or scientists in general, it is a recognition of the stuff that the players must have, and sometimes do have, to play the scientific game. In a world of relativity I rate the scientist high by virtue of his ideals and his strivings and his achievements as compared with those of others.

Our great opponent, nature, is vast in resource and subtle in method. We play what I fear is a losing game, where we can count on gains but not on victory. Our game must be played for the joy of the game and not for the sake of winning. For in the end nature will overcome us. She will inevitably defeat us as individuals, preserving an occasional rare specimen in her splendid paleontological collection, and returning the rest of us to her laboratory to be reworked into new experiments in plant and animal life or stored among her chemicals.

For nature is the great scientist and the great experimenter, who plays her scientific game on a vast scale, with man as one of her experiments. In all probability she will some day dispose of the human race in some such way as she disposes of us as individuals. When she

closes her books on this experiment, in which we are the guinea-pigs, we hope that in writing up her conclusions she will at least make passing reference to "this interesting experiment." That hope, at least, feeds our vanity and sustains that sense of importance which is so essential to human happiness. Meanwhile the scientist, who must suspend judgment on inconclusive evidence, may hope that we are important, but he will hold *sub judice* the question: Are we an important experiment or a minor experiment? For that matter, can any one say in science that one fact is more important or less important than another? It is a far cry from the simple experiments of Volta and Galvani to our modern electrical marvels, but were the parental voltaic pile and the observations on frog's legs swinging on hooks less important than are their children of radio, television and x-rays?

It may be asked whether there is any reason why a young man confronted with such ideas as are here expressed should elect to play this scientific game. And what may be answered: "Yes, if he has the qualities necessary to play it well." But what are the rewards? The rewards are mostly those arising from the difficulties. They are the rewards that come from playing intellectual games in which skill, courage and honesty are necessary, because these qualities develop by exercise, and the achievement of a greater intellectual keenness, courage and honesty is a high reward.

I have already said that the material rewards are not great. I would go further and say that there is a certain incompatibility between the service of science and the service of the god called Mammon. Among the poems, philosophical writings, history and other things which make up the Bible, there is a statement which seems to embody a sound economic and sociologic doctrine: "The love of money is the root of all

evil." The scientist can not dispense with money in his personal life or his scientific work, but the love of money and the desire for wealth are something else. In a wide acquaintance with scientists it has seemed to me only too evident that the scientist who conspicuously divides his energies between his work and his investments diminishes his value as a scientist proportionally. It still seems true of our intellectual and moral energy, as of other things, that "the more you dilute it the thinner it gets."

It may be said further that fame is a poor reward on which to focus the attention of the student who is considering the life of a scientist. We must take our work seriously, but only the scientist who takes himself seriously, which taking is itself a grave social sin, will greatly esteem his personal contribution to science. In laying upon us the limitations as to what may be achieved by adventures with the imperfect human brain and eyes and ears and nose and tactile sense, nature has fixed the status of the scientist in this fashion: He may achieve no final thing, but it is his rôle to maintain the continuity of scientific thought from the past through the present in order that the science of the future may move on more rapidly because of his work. As older players die, younger men step into their places, face the ancient opponent, struggle to advance the ball an inch or a yard, and give place to new players. There is no touchdown in sight, but for whatever reason may animate us, we play this game with a determination that no ground shall be lost to our great adversary by us. But not for fame, not for office and title and high headlines. For the love of the game and, in lieu of fame, for the regard and friendship of our scientific confrères who can best judge our work, and who, conscious of whatever of innumerable human weaknesses may be ours, still find our data valid and

our conclusions sound. Scientific verity and fame may be contrasted in the words Coth said to Dom Manuel: "But, master, we are men of this world, a world made of dirt. We pick our way about that dirt as best we can. The results need surprise nobody. The results are rather often, in a pathetic fashion, very admirable. Should this truth be disregarded for a vainglorious dream?"

I have said that the scientific game is not only a game of skill, but a gamble. As a gamble it has the appeal of magnificence. Many men gamble to put money in their pockets. The scientist gambles to add new and splendid stars to our galaxies, he gambles to enlarge the mental horizon of mankind, and he gambles to put millions of dollars in the pockets of other men. In spectacular fashion he has made possible our modern transportation and communication systems, and has left the profit and the glory of it all to the business man. He has restored the sick and healed the wounded. He has made, not two, but many, blades of grass grow where one grew before, and made better grasses. He has increased economic production in manifold fashion, and in no small way has brought upon the world the economic disaster that now overwhelms it.

For in this game with nature, the scientist has advanced our football of knowledge without regard to what humanity was doing as it followed him over the ground he had won. And what humanity has done has not always been in that spirit of splendid devotion to truth, courage and honesty which the scientist has sought to achieve and in some measure has achieved. It gives us pause to reflect on what we have done and on what has come from those achievements which looked so magnificent and seemed to hold such promise of good.

Perhaps there has been too much

singleness of purpose on our part. Perhaps we should have devoted less time to science and more to citizenship. For quite apart from all controversy of pure science and applied science, it is the thought of scientists that our work achieves either intellectual or material benefit to humanity. One may find here and there the scientist who professes no concern with humanity, but only with abstract truth. Such scientists stand on a somewhat shaky pedestal, for the downfall of civilization and of humanity must be the destruction of science. If the elaborate structure on which science now rests should fall, a scramble for edible roots and berries may be confidently expected to occupy our energies to the exclusion of the search for abstract truth.

As scientists, however, we may doubt whether the mathematician should devote less time to calculus and more to citizenship, whether the veterinarian who is gambling a few hundred dollars and the lives of a dozen cows to save millions of dollars and thousands of cows for other men, should curtail this practical work in economics to study tariff bills. It would seem better that our fellow citizens play their games of politics, economics and sociology in the scientific spirit. The basic intellectual essential of the business man for thousands of years has been the elementary ability to buy for one dollar and sell for two dollars, but even with such meager minimum intellectual essentials, industry has learned to employ the scientist to do its research and to point out the application of that research. To be sure, industry, by and large, has paid trivially for scientific brains, but industry has at least learned to use them.

It is now high time that in politics we began to play the scientific game and to consult the economist, sociologist and psychologist who have specialized knowledge of the raw materials from which

society and its activities are made. I realize that not all scientists will agree with this thought, but it seems to me that my dissenting colleagues are either defeatists who expect man to fail to solve his social problems, or are paying homage to the magicians when they expect those problems to be solved by our current stock of politicos and magnificos. In the hurricane of economic disaster now blowing around our planet, one seeks in vain among the organizations of our non-scientific great ones for some weather bureau that has charted the origin and course of this storm and can predict its duration and possible termination. Our great minds prescribe a dose of confidence or headache powders, or pass laws ordering a restoration of prosperity, or even suggest the madness of a greater storm in the form of war as a cure for our ailments. Some of the great medicine men are advocating a good dictator, but as a zoologist I note that nature preserves species and wastes individuals, I note that dictators, good or bad, share our mortal impermanence, I see that referring the problems of nations and centuries to individuals who die is only a motion to postpone, and I look askance at all such simple solutions of governmental problems as savoring of the usual moronic demand for a magician.

And so I turn to scientists for a solution. As scientists we must stand on the platform of *Nil sine numine*. Behind this phenomenon is its noumenon, and for these visible effects there are proportionate causes. These relationships are discoverable to scientific inquiry, and the time to learn them is ripe, if not over-ripe. If scientists can not solve our problems, we must accept defeat, but we shall only waste time by awaiting the miracles of the magician.

It is preposterous to assume that, if a savage can comprehend his simple culture, a civilized man can not compre-

hend a more complex culture if there is as much rationality in it as there is in that of the savage. If civilization is not rational, it must be shaped to a rational pattern. We can not concede that the race which produces men who tear atoms to pieces and follow the course of remote comets can not produce men capable of organizing and managing those affairs by which we might all be comfortably fed, clothed and housed. If man's morals, ethics, emotions, habits, customs and needs constitute a baffling mixture, so, too, do the composition of proteins, the functions of the brain, the structure of chlorophyl and the innumerable radiations in physics, yet we make progress with these latter things, and probably shall with the former. If the overlords of society have failed, it is not because they have used the scientific method. As scientists we may still believe that the solution of social problems will follow from the application of the scientific method in sociology as in the physical and biological sciences. For that matter, sociology and economics are biological sciences, for *Homo sapiens* is an animal, whatever else he may be or hope to be.

In government, which, after all, is only the collective business of social groups, we must adopt the scientific spirit. We must demand of the politician, as we do of the scientist, that he bring to his job an adequate fact content of knowledge and an increasingly large measure of intellectual keenness, courage and honesty. We must discourage the childish view that fame and fortune are of themselves admirable and desirable things. We must combat our belief in magic. There is no easy way to scientific achievement or worth-while achievement of any sort. There is only the way of intelligent effort, and intelligent effort implies that the mind and our physical force must be exercised. Magic always implies the easy way of the wishing ring,

the magic carpet or Aladdin's lamp, wish fulfilment by the simple process of wishing. This is still the method of politics. Only a very naïve mind can believe that majority votes can select ability, courage and honesty offered on a propaganda basis.

To qualify as a candidate for junior scientist, competent to play the scientific game in the government service at \$2,000 a year, a salary now likely to be marked down in order to help unemployment and restore prosperity, the law provides that a man must be a graduate of a recognized college, must pass an examination in his subject-matter, and must present an acceptable thesis. To qualify as a candidate for the presidency of the United States at a salary of \$75,000 a year, the constitution provides that a man must be 35 years old, a natural born citizen and have lived in this country for 14 years. With all due respect to the high occupation and standing of the scientist, one can hardly escape the conclusion that our requirements for a president are not sufficiently exacting, and experience indicates that not all presidents have had much beyond these minimum constitutional qualifications. Surely the qualifications for the head of this great government should be somewhat higher, more detailed and rigid. If the scientist must have education, training and experience qualifying him for his job, if he must have intellectual keenness, courage and honesty for his individual combat with nature, something of the sort must be demanded of the politician who is to conduct our collective combat with nature, magic, and our social parasites and predators.

Perhaps the application of civil service qualifications to candidates for office would help to make democracy the practical system that it must be if it is to supplant autocracy permanently. If only competent candidates can qualify for presentation to the electorate, it will

not matter so much which one is elected. It would be simpler to improve the quality of candidates than to raise the I. Q. of the electorate.

You will not fail to note that from science in general, I have selected for special consideration the fields of economics and sociology. The reason is sufficiently obvious. Science is a product of civilization, and over our civilization of to-day hangs the threat of economic destruction, war and revolution. To that crisis science has contributed through the material applications of its work to production and to industrial and agricultural developments. In the face of possible economic and social catastrophe, it matters that research go on, but it matters more that what has been won be held and not lost. Hurricanes and fires will destroy laboratories as well as homes. It is possible for all companions in science to uphold the hands of our associates in economics and sociology in whatever efforts they may make to combat magic and magicians, and to bring the scientific method into a world of economic and social chaos. Not only scientists but mankind must learn to play the scientific game, for nature will play her part as destroyer if we fall afoul of her laws. She will turn hunger into despair,

and pity into rage. It is not only in our laboratories that nature's workings are to be observed. She works unceasingly within us and throughout the body politic.

The scientist has a rôle to play in teaching the scientific game to others. Not in a spirit of reform or uplift, but in the spirit of scientists we must do our share to extend the scientific method of experiment and observation, of valid data, sound conclusions and constructive recommendations to our communal affairs, and to apply to our affairs what the world's history of the past and the world's experience of the present can teach us. Not to do so is to leave the world outside our laboratories to the magicians and their worshippers. In the ancient and medieval world magic could play its rôle the easier because of the lack or scarcity of science, but science and magic can not exist side by side in the modern world without serious conflict. Either science must supplant magic, or magic will wreck science. Scientists can not look on this combat with academic disinterest. They must play the scientific game intelligently, courageously and honestly against the magician as well as against their ancient adversary, nature.

SCIENTIFIC DISCOVERY AND HUMAN OUTLOOK

By Dr. GEORGE F. KAY

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NEAR the close of the nineteenth century Pasteur wrote: "In our century science is the soul of the prosperity of nations and the living source of all progress. What really leads us forward is a few scientific discoveries and their application." He said, also: "The cultivation of science in its highest expression is perhaps more necessary to the moral condition than to the material prosperity of a nation."

And now in the early years of the twentieth century important scientific discoveries are exerting a more profound and wide-spread influence upon human thought and action than perhaps at any previous time—this influence being upon the physical, the intellectual, the philosophical and the spiritual well-being of peoples everywhere. The many recent discoveries in all the important branches of science are being discussed to-day not alone by the specialists but by laymen in every walk of life, in every community. Questions are being asked and answers sought in every classroom, in the home, in the church, and on the street. What, it is asked, is the meaning—the constructive message—of the thousand and one facts which science has brought to us? And what of the to-morrow? Do not many of the questions give evidence of bewilderment, misinterpretation, lack of intelligent understanding of present-day problems and no clear vision as to the future? And all too often the scientific men themselves have been so absorbed in looking through their telescopes and their microscopes that they have not realized their obligations, not as scientific men necessarily but as human beings, to interpret, insofar as they

are able, to their non-scientific friends the significance of the facts which they have discovered. As Agassiz once said, "Facts are absurd things until they are linked up with something." Is it not evident that we scientific men are not doing our proper share in helping men and women to get an adequate appreciation of the background of the present, a clearer understanding of the path along which the human race has come and some wholesome conception of man's future destiny?

Without attempting at once to give specific answers to any of the questions which have been raised or to make at this point any generalization with regard to human outlook, it will be helpful to all of us, I am sure, for me to present, if only in bare outline, some of the views which have prevailed in the past regarding Nature and some of the important concepts which are held to-day by scientific men based upon their detailed investigations, more particularly in astronomy and in my own special field of study, geology. Let me hasten to state that no consideration will be given at this time to scientific discoveries in their application to industry or to our material development, but our attention will be restricted to some facts of science as a key to the understanding of man's place in the universe and of the part he is destined to play in the years which lie ahead.

Study of primitive man—as, for example, the Cro-Magnons—who lived in caves probably twenty-five thousand to forty thousand years ago—has shown that they had already developed a distinct interest in nature. Witness their drawings of landscapes and animals on

the walls of their abodes. Dr. Henry Fairfield Osborn, the noted anthropologist, has stated that there is every reason to believe that this race "could compete in the art schools with any of the animal sculptors and painters of our day." Many thousands of years later, as revealed to us in the translations of the hieroglyphic languages of ancient civilizations, the Babylonians, the Assyrians, the Egyptians and the much younger stock of the Semitic peoples, the Hebrews, had developed the scientific attitude of mind and had an almost unbelievable knowledge of the celestial world. Literature written in the twelfth century B. C. reveals man's love of beauty in nature and "the great Pyramid of Gizeh," says Breasted, "is a document in the history of the human mind. It clearly discloses man's sense of sovereign power in his triumph over material forces." Then came Thales, the Greek, announcing that theory can and must be fitted to fact, which is the recognition of a foundation principle of all science. Centuries later came Copernicus, who put forward the view that our earth is not at the center of the universe, as had been held up to this time, but is one of several planets revolving around our sun, which is the center of our solar system. This new view of Copernicus, given to mankind only about four hundred years ago, "set the feet of man," said Newton, "for the first time firmly on the road leading to knowledge of the universe, and opened up a new epoch in the development of the human mind."

Now let us come nearer to our own day. Let us recall to our minds the scientific discoveries since Copernicus, but more particularly of the last fifty years. The scientific man is investigating to-day, is he not, everything which lies between the ultra-telescopic on the one hand and the submicroscopic on the other. He is working eagerly to satisfy his curiosity as to what is beyond the

most distant star, what cosmic rays are, and what is within the tiny atom itself—the electrons, the protons, the neutrons and the alpha particles. Scientific men to-day have faith not alone in things which can be seen but in things invisible. We are indeed living in what has been called "The Wonderful Century."

What, then, are some of the significant facts which are the result of scientific discovery? What are some of our present-day concepts about the universe, our solar system, our earth and the history of man? Simon Newcomb once said: "If it be true that in nature nothing is great but man, in man nothing is great but mind, then may knowledge of the universe be regarded as the true measure of progress." It is now well known that our sun is but one star of millions of stars which circle about one another in a star system, and that this star system is but one of millions of star systems in the universe. If a star in one of the most distant star systems should suddenly explode it would take light which travels 186,000 miles per second more than 200,000 light years to get the news to us on the earth. The immensity of space is beyond the comprehension of the human mind. Dr. Hubble, of Mount Wilson Observatory, has estimated that the universe apparent to man does not extend more than a certain multiple of millions of trillions of light years from the earth. Was it not Pascal who said, "The universe is an infinite sphere with center everywhere and surface nowhere"? But enough of the universe, you say. Give us some facts about our own solar system and about the earth, the planet on which we live. Such facts will be of more direct concern to us. It was Herschel who suggested a method by which a proper conception could be gained of the relative sizes and space relations of the planets of our solar system. If, he said, our solar system were represented within a sphere, with a radius of $1\frac{1}{4}$ miles, and if our sun were

represented at the center of the sphere by a globe two feet in diameter, it would be possible to represent the planets which revolve about our sun, as to spacing and sizes, on the $1\frac{1}{2}$ mile radius. In such a scheme Neptune, the outermost planet (until the discovery of Pluto recently), would be at the end of the radius and would be represented by a plum, Uranus by a cherry $\frac{3}{4}$ of a mile from the sun, Saturn by a lemon $\frac{5}{8}$ of a mile from the sun, Jupiter, the largest planet of our system, by an orange $\frac{1}{4}$ of a mile from the sun, Mars by a pin-head 327 feet from the sun, our earth by a pea 215 feet from the sun. Nearer to the sun than the earth would be Venus and Mercury, the former represented also by a pea only 82 feet from the sun, and the latter, Mercury, the smallest planet, by a small seed two feet from the sun. Let me repeat, our earth would be a pea 215 feet distant from the sun. How small a part of our solar system is our earth! And, as has been stated already, our solar system is but one of millions of solar systems in the universe.

And now for some facts about the earth itself. The geologist, for more than one hundred years, has been unraveling the fascinating story of this planet on which we live. Dr. J. C. Merriam, of the Carnegie Institution of Washington, himself a distinguished geologist, has said "The geological record is the greatest historical document of all the ages"; and the nature poet, Walt Whitman, has written:

The earth is rude, silent, and incomprehensible at first,
Be not discouraged—keep on—there are divine things well enveloped,
I swear there are divine things—more beautiful than tongue can tell.

The books in the library of the earth have now been read. The manuscripts are the rocks themselves—the limestones, the sandstones and the shales—with their included records of the life of the ancient seas and lands. The rock-form-

ing processes have been active throughout the ages. By one of these processes, called gradation, layer upon layer of rock has been laid down—superimposed books, the oldest at the bottom to the youngest at the top.

The face of the earth throughout its history has been undergoing change continuously. The areas of land and sea have been ever shifting. Running water and other agencies have been tearing down the continents, carrying the materials of erosion into the sea, and there depositing them. Each day the Mississippi River carries in its waters and deposits in the Gulf of Mexico more than a million tons of sediment—four hundred million tons a year. If nine hundred trains, each of fifty cars and each car loaded with 25 tons of sediment, were running parallel to the Mississippi River day and night without stopping, these trains could dump into the Gulf only the amount of sand and silt that the Father of Waters is now carrying. The shore lines of the oceans are never the same during any two successive seconds. The only permanent thing is change, and so it ever has been throughout the earth's history. As Tennyson has written:

The hills are shadows and they flow
From form to form and nothing stands;
They melt like mists—the solid lands
Like clouds—they shape themselves and go.

Where the mountains now are the seas have been time and time again. Widely distributed on the continents are rocks with their cemeteries of past life.

There rolls the deep where grew the tree,
O earth, what changes thou hast seen!
There where the long street roars hath been
The stillness of the central sea.

Let us return to our library. The history involved in the records of the earth when traced back and back to the most ancient record available for study at the face of the earth has been estimated from our most reliable data to be

probably 2,000 million years. The geologist has found it convenient to divide this immense length of time into five great eras, during each of which there was written in the rocks what we may choose to call a volume in the library of the earth—five volumes in all, in which is found the story of the onward, upward, march of life from lowly organized forms to the highest types of animal and plant life which inhabit the earth to-day. Volume I, the most ancient part of the available record, may have involved 800 million years. The oldest chapters of this volume indicate clearly that life was already in existence and possibly had been for hundreds of thousands of years, even long before the earth had attained its full size.

From Volume II, which involved also a very long time—probably more than 650 million years—the kinds of life which frequented these ancient seas have been determined. These and the earlier manuscripts of Volume I have been much changed by great heat and great pressure resulting from profound earth movements and extensive volcanic activity. In Volume III, abundant and wide-spread life is found—invertebrates—marine and land forms—and vertebrates—fishes, amphibians and reptiles. Trees and plants, too, of great interest to the paleobotanist, were distributed widely. Some of our most important coal fields bear witness to this chapter in the history of vegetation on the earth. The time included in the making of Volume III was not as great as that of the preceding volume, probably not more than 350 million years. In Volume IV, of still shorter duration—involving probably not more than 140 million years—the reptiles were the masters of the day; not only were they present in great numbers, but they were of huge size—sluggish creatures, some herbivorous and some carnivorous, all with deficient brain capacity. The struggle for existence was terrific.

Some tried to maintain themselves on the land, some attempted to adapt themselves to life in the sea, and some developed the ability to fly—flying reptiles with a spread of wing of twenty feet. Nature surely at this time tried an unusual experiment—she resorted to the development of the maximum of the physical with a minimum of the mental—size without intellect—and the result was failure. But perhaps we should not say failure, for did not John Burroughs once say "Nature always hits the mark because she shoots in all directions."? These colossal, lazy dinosaurs and related forms passed from the stage as the last chapter of this Volume IV was being written. While these huge reptiles were still abundant, birds were evolved and a few small mammals. What of Volume V? It is only in this volume which goes back to about sixty million years from the present that the paleontologist finds evidence of the rapid and wide-spread differentiation of the mammals—the haired animals. The most highly organized of these mammals—the Primates—were living when the earlier chapters of Volume V were being written, but man, the highest of the Primates, came upon the scene only comparatively recently, in that period which lies just back of the Recent, geologically—the Pleistocene or Glacial Period. And as yet the cradle of the human race has not been determined with definiteness. The earliest remains of human species have been found as widely distributed as Java, Southeastern Asia, Germany and England. And, according to the most reliable estimates, man has been on the earth at least a million years. But he is a resultant of a history linking him back and back to the beginning of life itself; yes, and still farther back to things inorganic. He is made of the stuff of the universe itself. Only as we come to understand the universe can man be fully understood—universe, solar system, earth, life, man—

infinite space, infinite time, and, shall we say, infinite life.

A fire-mist and a planet; a crystal and a cell;
A jelly-fish and a Saurian, and caves where the
cave men dwell;
Then a sense of law and beauty, and a face
turned from the clod;
Some call it Evolution, and others call it God.

Onward and upward to man—man a resultant of the processes of the ages—weak physically but strong mentally—with power to look back and unravel the line of his descent, to analyze himself in relation to all other life with which he is associated, and to conceive and plan his own future. Another of nature's experiments, you say, but this time brain power, not brute strength is at the helm.

And, what of man's future? What is the human outlook? What will Volume VI reveal? Surely the answer to this question is of vital concern to all of us, but more especially to those who are still young—preparing to play their parts in the great drama of life. Does our knowledge of the past and of the present enable us to make any trustworthy prediction as to the future? Chamberlin, the world-famous geologist, said: "The forecast is at best speculative, but an optimistic outlook seems more true than a pessimistic one. An immeasurably higher evolution than that now reached, with attainments beyond present comprehension is a reasonable hope.

"The forecast of an eon of intellectual and spiritual development comparable in magnitude to the prolonged physical and biotic evolutions, lends to the total view of earth history great moral satisfaction, and the thought that individual contributions to the higher welfare of the race may realize its fullest fruits by continued influence through

scarcely limited ages, gives value to life and inspiration to personal endeavor." And Sir James Jeans, the astronomer, about whom much is being heard in these days, has written in one of his recent books: "By what light we have, we seem to discern that the main message is one of hope to the race and of responsibility to the individual—of responsibility because we are drawing plans and laying foundations for a longer future than we can well imagine." And Conklin, the well-known biologist of Princeton University, has predicted that the next great step in human progress will be social—the development of social interrelationships of the human race—the different races of mankind learning to live with one another without destroying one another.

We are living in the aftermath of a great war. In the words of General Smuts: "Humanity has struck its tents, and is once more on the march. A new adventure is beginning, a new search for justice, perhaps—who knows? A new Renaissance."

Surely man has the mental power and insight to enable him to realize that his future can be best insured by the cultivation of the spirit of cooperation and the abandonment of "the tooth and the claw" of his less endowed relatives of the past and present.

Only through the united efforts in research of scientific men, humanists, philosophers and theologians, in every country of the world, will we gain a still better understanding and a clearer appreciation of what man is and of what God is. Then will we be able perhaps with clearer vision than at present to interpret the meaning and purpose of our own lives and to plan effectively for man's future welfare.

THE TROPICAL AMERICAS¹

ETHNOGRAPHY AND MEDICAL GEOGRAPHY

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FROM the medical standpoint, the western hemisphere falls into natural geographic rather than political divisions. The major portion of South America, all Central America and the southern fringe of North America properly come within the scope of tropical climatology. This tropical region in general consists of two major and three minor areas. Of the major areas, the smaller, of greater importance now, comprises the shores of the Gulf of Mexico and the Caribbean Sea with its islands, well called the American Mediterranean. The greater in extent, and perhaps of chiefer importance in the future, is the watershed of the Orinoco and Amazon Rivers. The three minor areas are: (1) The watersheds of the Plata and São Francisco Rivers, together with eastern coast of South America, (2) the mountainous and high plateau regions extending along the backbone of the continents from Bolivia through Central America into Mexico and the southwestern United States, and (3) the narrow coast lands bordering on the Pacific.

GENERAL

Disease incidence and even more, disease control, in the Americas are determined by two great factors. The first is the actual topographical climate and the second is the influence of the various immigrant races. Ethnologically, we find the primitive American Indians in

related types distributed thinly throughout both continents with records of special concentrations of culture and population in the mountains of Mexico and upper South America. These aborigines have been replaced, overlaid or intermixed with three general immigrational types. These streams of immigration have followed a peculiar course in general zones. North of the Mexican Gulf the north European or Nordic race and culture and psychology prevails. From the upper Mexican boundary, the rest of this district has been the site of Latin or Mediterranean influx, with Spanish as the language basis of all countries, except Brazil, occupying nearly half of South America, where Portuguese prevails. The elements of tropical climate, added to the Latin character of the conquerors and the accessibility of Africa, made easy the spread of slavery through the entire region under discussion. The result is a heavy Negro and Negroid percentage in the population.

Spanish colonies were established especially on the River Plata, on the northwestern corner of South America, in Mexico and in Florida. Portugal colonized the east coast of South America and here African slaves were especially brought in. Whatever the respective merits of the respective claims to the discovery of America, the fact remains that the indomitable and unscrupulous will of Columbus first brought the western hemisphere to the attention of Europe. Sailing from Palos in Spain, he fulfilled the ancient prophecy of the Spanish-born Seneca, who,

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more than fourteen centuries before, had said that the ocean would loose its hold on things and a vast new land would be revealed and Thule would not remain ultimate. So, after Columbus, the "Ne Plus Ultra" across the Pillars of Hercules on the coins of Spain was changed to "Plus Ultra," and for three hundred years "More Beyond" was the watchword of the gold-maddened Spanish conquerors, who ruthlessly destroyed the ancient civilizations of tropical America, replacing them with colonies of exploitation and an age of piracy, destruction and brigandage.

Two pregnant speculations arise. Firstly, what different results might have followed if America had been discovered two hundred years later or if America had first discovered Europe. Under these conditions the character of colonization of tropical America would conceivably have been so different as to influence profoundly the matter of disease control in these regions and thereby the development of their resources in foods and in natural wealth. Secondly, if north European races had discovered and controlled the American tropics, we can readily imagine different results in character of colonization and development, when the desire for relief from persecution and for new permanent homes furnished the basic purpose. As it is, we have to deal with predominant Latin influence through all South America and up to the boundary of Mexico. In the tropical sections, this is mixed with the aboriginal Indian population and the African Negroes.

ETHNOLOGY

The ethnologic units of the New World thus include the North European, the Latin, the Negro and the Indian. The North European requires no detailed description. His aggressive, industrious, evolutional force speaks for itself. It remains only to note the effect

on his characteristics of prolonged exposure to hot climates and extended association with tropical peoples. Nowhere in the world are the results of such contact more important and their understanding more critically necessary than in the regions under discussion. The principles involved will be given more extended treatment elsewhere under the separate heading of the white man in the tropics.

The Latin temperament is more a product of a warm climate and its contribution to American culture in the broad sense is extensive and valuable. It is the contribution of direct emotional expression, of high appreciation of esthetic values, of warm enthusiasms, of intense personal loyalties, of great potentialities for keen thinking and originality of thought and of hard-working brawn. These elements are present throughout tropical America, but they have been handicapped by their corresponding weaknesses and have reacted poorly to climate and to the local populations. Languor and insufficient application have too much won the day. Under proper influences of climate and human contacts, the Latin character reaches untold heights. Failing these, it degenerates to the lowest of its associates and is submerged by the lethargy and monotony of its environment. This is largely what we find in the tropic zone of the New World. Greed, evanescent schemes, political instability, economic beggary, selfishness, insincerity and duplicity too easily creep in and are only held in check by the stronger Latin social units and by outside contacts.

These elements make the problem of disease control very great, and result in a need for public health work on a totally different basis from that in other hot climates. Disease vectors, disease incidence and disease cure and prevention become decidedly ancillary to the problem of dealing effectively with the

Latin temperament in a tropical climate. Probably the solution will be found by tracing our analysis back again to improved contacts with more effective human institutions, and to demonstration of the economic value of sanitation and disease prevention.

THE AMERICAN INDIAN

Few ethnological battles have waged with greater brilliance and keener strife of contending factions than that over the problem of the origin of the American aborigines. For the present purpose we are not concerned with deciding whether they came from Mongolia by way of the Aleutian Islands; from north Europe by way of land-ice bridges across Greenland; whether they developed locally, coequal with human origins elsewhere in the world; or whether they came both by island bridges in the north and also by fortuitous and accidental voyages across the Pacific from Japan, China, Malaysia and the Pacific islands. This last seems the most explanatory theory.

In any case the fifteenth century found a thin sprinkling of these generally reddish-skinned natives over all of both continents. To these Columbus applied the name of Indians, and priority as well as usage have established it in spite of its complete inappropriate-ness.

There are some evidences of a paleo- or at least neo-lithic race in North America, as in the Delaware River valley (H. W. Haynes, "Prehistoric Archeology of North America," in Winsor's History of America) which became extinct and had no relation to those later natives known as Indians. One of the chief difficulties in tracing the antiquity of the Indians has been the absence of associated domestic animals other than the dog (H. H. Howorth, "The Mammoth and the Flood"). Regardless of their origin and the length of their resi-

dence, at the time of the discovery, they were uniformly distributed through the American continents from the Esquimaux to the Fuegians. They had a general resemblance in color and configuration of head and face which showed a wide molar arch, medium nasal aperture, low orbital indices and a generally broad face (Brinton, "The American Race"). Their average cranial capacity is above that of the Negro and considerably below that of modern Parisians. Individual capacities have been measured of a size not exceeded by any race. (L. Carr, quoted by Brinton). The skin color is copper-like, reddish or cinnamon hued, a brown with an element of red. The darkest are not black and the lightest are not white. The hair is generally straight and coarse, dark but not black, heavy on the head, scantier on body and face. It may be fine and silky. (See Brinton, "The American Race," for full exposition). The average stature is probably under the European average, but there are many tribes in which there is a fair percentage of large individuals approaching the six-foot height. There are no dwarfs or pygmies among them, with a few exceptions in the Amazon jungles. Small hands and feet with long arms are characteristic.

Various factors help explain the remarkable similarity of types throughout both continents. In general, the mountain systems and rivers of the western hemisphere are arranged longitudinally, making for geographic ease of migration in line with the continental axis and permitting early free diffusion. The chief exception to this rule is the Amazon River, which flows from west to east, but which in its long lower course is more an estuary than a river. Its chief tributaries follow the rule given. Another element making for uniformity is probably to be found in a general com-

mon origin of the Indians from a single racial type.

In mental endowment the Indian can be judged from two standpoints. In the first place, the testimony of many travelers and observers of scientific ability agrees in ascribing to many tribes on both continents a position of mental capability below but comparable with the white race. In the second place, judgment by degree of achievement shows some interesting comparisons. It is easy to fall into the error of considering what is different as inferior. This is a common fault in our estimation of tropical and especially of oriental races. The American Indians showed considerable ability in political organization and government. The Iroquois League in the north and the Incas in the south were eminently successful states of long duration, definite policies and wide dominion. Full-blooded Indians under modern conditions have been active in this line, as President Benito Juarez, of Mexico, President Barrios, of Guatemala, and many others. In architecture, art, agriculture, mining, as well as in personal qualities, the Indian has shown and shows great capacity. He is, however, decidedly not adaptable to a foreign culture or civilization.

Cultural advancement has not been a matter of race or tribe but primarily of location. With a close ethnic unity the Indians none the less exhibit a surprising variation in culture and achievement. This extreme variation extends to the languages, which are very numerous and to a high degree dissimilar. We find the explanation of their advancement by considering the locations where it has been most marked. The eastern United States and the high plateau regions of Mexico, Yucatan, Guatemala and the northern Andes all enjoyed a healthful climate, with necessary variations between heat and cold. They afforded reasonable natural protection

from enemies. They were reasonably free from insect vectors of disease. They were sufficiently isolated from human contacts with contagious disease. Conditions of climate, savannah and water supply permitted agriculture. In these sections all the local tribes shared in the advancement. It was not limited to a certain tribe or race. It was a result of favoring environmental factors.

So outstanding is this situation that it raises at once the query as to why the Indian could not again respond to a favoring environment by cultural achievement as great, if not of necessity along the same lines, as 400 to 1,000 years ago. Where climatic conditions are now suitable, improvement of economic and political status becomes, therefore, a part of public health work, since disease control is based on intelligence, and the evolution of intelligence in the past has been rather determined by location than by particular personal gifts. Where climatic conditions are unfavorable, sanitation and public health must be introduced first from without, and imposition of decreased disease risk becomes the primary civilizing factor.

Three great facts must be remembered in dealing with the American Indians. All are based on the ethnic unity of all the tribes north and south. All recognize the tremendous diversity in languages (estimated at from 126 to 400 in number), in culture types and in advancement. The Mayan, Aztec and Incan cultures, at one extreme, were emerging into civilization, while the northern tribes were well above the level of savagery and the southern tropical tribes of jungle and savannah were still savage. In general, the Indians were slowly rising in civilization, the extent and rate of the rise being largely determined by their environment.

(1) The matter of early relations between Indians and whites. No known

race of men surpassed the North American Indians in absolute cruelty. The nomadic tribes had no true claim to the territory over which they roamed. When opposed by home-seeking white men of a superior civilization, their atrocious cruelty merited the sternest repression possible. They were masters of a new art of warfare which the whites learned from them with revolutionary results in world methods of warfare. The writings of Thwaites, Francis Parkman and Theodore Roosevelt should be consulted for more detailed treatment. After the warlike northern tribes, we consider the more agricultural tribes of the warmer climates both north and south, who were semi-savage and barbarous. These races made little effective opposition to the conqueror and were ruthlessly pushed out of the way of the whites. Finally, we consider the races of the mountain plateaus of Mexico, Central America and the northern Andes, which represented the acme of Indian culture and civilization. In all their explorations and conquests, covering the huge territory of South and Central America, Mexico and the lower third of what is now the United States, the Spanish conquerors were actuated by one consuming motive only—the inordinate lust for gold. This led to absolutely unscrupulous destruction of the best Indian cultures, in Mexico and Peru, and to a type of colonization for exploitation which was short-sighted, unmindful of native populations, and not designed for permanent new homes. Associated with this was the principle of black slavery, whose extension to the Indians was attempted, largely without success.

(2) The highest possibilities of the Indian in civilized advancement were realized among the Incas and the Aztecs and associated races of Mexico. This civilization was, at its best, greatly inferior to European civilization of the

day and has been exaggerated and idealized. They had, indeed, an organized city life, excellent stone architecture, hieroglyphic writing, the beginnings of phonetic writing and a type of lavish luxury. Even the highly advanced Teyucans, who preceded the Aztecs in Mexico, did not reach the level of European civilization either in the accomplishment or in elements of permanence or continued progress or in contribution to human welfare. In passing judgment, we must, however, remember constantly the risk of considering as inferior what is merely different. In any case, the best of Indian culture was destroyed by the Spanish conquest and has not yet been resurrected. The descendants of those days are ignorant, superstitious, devoid of ambition, taking pleasure chiefly in alcohol and dancing.

(3) Finally, it is a matter of importance that the American Indian races have made a large contribution to the present constitution of the nations of the western continents. This is much less marked in the United States than to the south. To a considerable degree, however, the North American Indians have been absorbed into the white population. Starting with the north Mexican boundary, the aboriginal races are of immediate prominence in every nation except Argentine and Uruguay, which are almost entirely white. Of the fifteen millions of Mexico, Bryce estimates eight millions as pure Indians, six millions as mestizos and one million as Spanish. (See James Bryce, "South America," 1913). Paraguay is purely Indian and speaks Guarani. In general, Bryce accepts forty-five millions as the population of South America, of whom about one fifth are pure Indians, and about one third mestizos. Excluding Brazil, with its large Negro fraction, white Uruguay and *nearly white* Argentina, and confining "our view to the other eight republics in which the Indian element is

larger, a probable estimate would put the number of pure Indians at more than double that of the whites, and a little less than that of the mestizos." It is to be remembered also that the mestizos rank with the whites and together form the ruling class, socially and politically, the Indian element "being passive and in a political sense outside the nation."

The Indians furnish the rank and file of armies, fighting cheerfully and methodically for causes they care nothing about, and they also are the chief reliance for common labor.

NEGROES

There are approximately eight to nine million Negroes and mulattoes in South America—chiefly in Brazil. Fewer of them are found in Peru, where the "Zambos" represent Indian-Negro mixture, and a scattering in other countries. Their preponderance in Brazil is due to the old Portuguese slave trade from Africa. A second center of Negro population is found in the West Indies. In these islands slavery came with the Spanish, who forced the Indians to work in mine and on plantation. African slavery followed and the predominant blacks of to-day are descended from African slaves chiefly brought by the Portuguese and Spanish. The black republic, Haiti, and the nearly black Santo Domingo are interesting examples of self-government, virtually under foreign protectorate, and are very backward politically, socially and economically. The third great Negro center in the western world is in the United States. Here is found the largest, most progressive and most advanced group of Negroes in any country outside of Africa. They number approximately eleven millions, and constitute about one third of the population of the Southern states. Since the Civil War, while it is possible that the lowest tenth has retro-

graded, it is certain that the highest tenth has advanced immeasurably. Miscegenation is relatively far less common than in the West Indies and Brazil. Many Southern states forbid marriage between whites and persons who have one eighth or more of Negro blood. The mulatto class represents to a considerable degree illicit unions. Color prejudice is strong, and since the end of post-bellum reconstruction, in 1877, there has been a practical disenfranchisement of a large portion of the Southern Negro population, with probable advantage to both whites and blacks. While large numbers of Negroes have migrated to northern states, as to New York especially, climatic conditions make the south his best United States habitat. The Negroes constitute economically an important unit of population in the United States. Their future has good prospects, but the question of racial absorption is very doubtful and equally important.

THE MEXICAN GULF COASTS

The coastal plains of the Mexican Gulf begin with the peninsula of Florida and terminate with the opposing peninsula of Yucatan. In that portion lying within the United States, three geographic features are of medical interest. (1) The Floridan peninsula has an underlying, easily eroded limestone base, which leads to much underground drainage of the lowlands with many sinkholes. The great Everglades marshes dominate the southern portion, while at the tip is found a series of coral reefs growing out against the gulf stream, which brings their food supply. (2) The coastal plain in Alabama and parts of Mississippi and Texas is low and rich, averages 150 miles in width and shades off into lagoons and marshes. (3) The huge embayment of the Mississippi River extends up the river course for some 500 miles and includes the great delta region. The Mis-

sissippi drains one third of the United States, and its lower course has a fall of only half a foot per mile. It carries annually into the Mexican Gulf a load of soil which would be 312 feet deep over one square mile. Its load of alluvial deposit is a great factor in its tendency to wander into new channels and in building up the delta itself. At low water, 300 miles from its mouth, the river level is little more than 5 feet above the level of the Gulf and in the latter the tidal variation is less than 15 inches, making the river simply a fresh-water lake nearly at sea-level. At high water a rise of 50 feet gives sufficient head to carry the enormous volume of water into the Gulf.

The great system of dykes or levees, nearly 1,500 miles in length, is a distinctive feature of the Mississippi, together with the huge floods which become maximal at five or six year intervals. More than \$70,000,000 has been expended by the United States Government alone on control of this waterway to keep it navigable and limit flood damage, between the mouth of the Ohio River and the Gulf. This is additional to the expenditures of the adjacent states. The Mississippi River is of great medical importance, because of the wide extent of its flood basin, much of which is habitable under levee protection; because of the marshes, lakes and low grounds which border it; because of its again increasing importance as a commercial waterway; and because of the subtropical climate in which its lower course lies. From its mouth to the source of its great tributary, the Missouri, it is the longest river in the world, 4,221 miles. It is comparable to the other major water courses of the world. Its floods and the nature of its alluvial flood basin raise problems for the sanitarian similar to those of the Yangtse and Hoang-ho. When pressure of population has increased, these problems will

be duplicated in the Amazon, Orinoco and Congo. Its huge delta, with salt marshes gradually giving way to fertile black land, is comparable to the delta of the Nile, which is 100 miles deep and 155 miles wide. Backwaters, marshes and periodic flooding raise problems of insect control, sewage disposal, water supply and atmospheric humidity which are primarily sanitary, that is, medical, and on which its civilization and habitability depend.

West from the Mississippi embayment, the coastal plain is marshy towards the sea through Louisiana and the Texan coast, gradually blending through low hills with the hot dry plains of Texas. Cypress swamps and alligators, mosquitoes and scattered huts and villages, built on higher ground or piling, express the landscape. This coast is continuous with the coastal hot belt of Mexico, reaching its insanitary apotheosis in the hot, humid, healthless Rich City of the True Cross, Vera Cruz, whose site and name were determined by the avarice and religious fanaticism of Cortes, who here found fertile soil, a good harbor and a base for attack on the rich Aztecs, but no sanitary or health advantage. Vera Cruz has been one of the disease centers of the Mexican Gulf throughout its history, combining its rare advantage for disease incubation with a population indifferent to sanitation and tolerant of all disease-fostering influences. In the United States, Mississippi, Arkansas and Louisiana are only exceeded by Florida in extent of swamp lands.

The embayment and delta of the Rio Grande reproduce on a smaller scale the outlet of the Mississippi River. Large rivers are not found in Mexico or Central America, because the high plateau which is dry and largely treeless leaves only a narrow belt of lowland, the tierras calientes. Yucatan has no rivers. Many of the Gulf Coast rivers are navigable for short distances, the Orijalva in Ta-

baseo, even for 93 miles. They are largely obstructed by bars and silting. Many navigable lagoons border the coast and a remarkable series of banks has been built several miles off the north coast of Yucatan by the Gulf Stream. Owing to silting and bars, Mexico has very few good Gulf ports, Vera Cruz, Tampico and Coatzacoalcos being noteworthy.

The tierras calientes, or hot lands, include the narrow Pacific and Gulf coastal plains, the isthmus of Tehuantepec, the states of Tabasco, Campeche, part of Chiapas and Oaxaca and the Yucatan peninsula. In this belt the elevations rise to 3,280 feet at most and, except in Yucatan, the fertile soil and heavy rainfall, approaching 100 inches annually in Vera Cruz, result in dense forests of marvelous richness. The unhealthiness of these lowlands alone prevents aggressive development commercially. Yucatan peninsula is in general under 200 feet above sea-level. It is largely unforested, has a porous soil, hot sun temperatures cooled by fresh sea breezes, abundant rainfall in the wet season, which, however, is quickly drained off, and a long dry season. It has, therefore, a fairly hot, dry and healthful climate, similar to that of the Pacific lowlands of Sonora. Only in the extreme north of Mexico, above the 28th parallel of latitude, are there four distinct seasons. For the rest, the lowlands have a rainy season from May to October and the balance of the year is the dry season.

Above the tierras calientes rises the tierra templada or temperate zone, to an altitude of 5,577 feet. From this up to 8,200 is called the tierra fria and includes the higher Mexican plateau, with hot sun temperatures, rare frost and a really subtropical climate and flora. Animal life in Mexico is interesting in that the tropical species of the south and the Gulf coast extend well up the warm coastal plain into the United

States, while the temperate climate animals of the United States are found extending far south through the high central plateau region. In the southeast, the fauna resemble the Amazonian types. Of the plant life, chief mention should be made of the agave (including the "century plant") or magney of the plateau, from which the national drinks, pulque and mescal, are made. While these plants are important sources of textile fibers, their medical importance lies in the heavy and wide-spread use of the alcoholic beverages made from their juices. Mixed blood, climate, disease and alcohol are the great foes of Mexico. The forests of the tierras calientes are among the finest in the world. They include 114 varieties of trees and cabinet-woods, 17 oil-bearing plants and over 60 medicinal plants and dye-woods indigenous to Mexico. Here are found jalap, ipecac, sarsaparilla, rubber and a large number of gums.

THE CARIBBEAN SEA

Among the most adventurous and romantic chapters in the history of America is the story of the Caribbean Sea, well called the American Mediterranean. Its northern limit is at the Yucatan-Florida strait. Its western and southern shores wash the tropical coast of Central America, Colombia and Venezuela. It is separated from the Atlantic by a chain of mountain tops reaching up into the West Indian islands, stretching from Trinidad to Florida. Following the Spanish Conquest, this area was colonized and claimed in its entirety by Spain. Spanish monopolies in trade, export and industry led to vigorous opposition by adventurers and traders from England, France and Holland, whose private exploits and greed for the riches of Spanish America grew rapidly into the loosely confederated system of buccaneers (which see) who terrorized tropi-

cal American waters in the seventeenth century. The buccaneers were actuated by two principles, bitter hatred of Spain and greed for the wealth of the Caribbean countries, including the products of the South American mines which came across the Panaman isthmus to Porto Bello for transshipment to Spain. Finally disappearing as a result of their own methods and by the treaty partitions of territory between the powers concerned, the buccaneers none the less left their mark on this great region both historically, politically and socially.

The West Indian islands are divided in sovereignty between Great Britain, which holds chiefly Barbadoes, Bahamas, Jamaica and the Lesser Antilles; France, which holds Guadeloupe, Martinique and part of St. Martin; Holland, holding several small islands; the United States, with Puerto Rico and the Virgin Islands; and the three republies of Santo Domingo, Haiti and Cuba. Climate is greatly influenced by altitude, as is the case in all tropical countries. Out of some 100,000 square miles of island territory, nearly 16,000 square miles lie above 1,500 feet in elevation. Except the Bahamas, all are between the isotherms of 77 and 82 degrees Fahrenheit. Coolness is found in the higher areas with typical tropical conditions below. The seasons consist of a short wet season of two to six weeks, beginning in April, followed by the short dry season, reaching its climax in the extreme heat of July. With October the heavy rains set in, often associated with the terrific and destructive hurricanes. (See Chapter—Disasters, etc.). These are known as the "hurricane months." From December to April comes the long dry season. The average annual rainfall is well over 60 inches.

The great prosperity of these islands is not due to mineral deposits, in which they are quite deficient, but has followed the introduction of sugar-cane in the

middle of the seventeenth century. Cocoa, fruits and cotton are also of major importance. These facts all have important medical results, as the tropical climate, with the predominant Negro and Latin population, extreme fertility of soil, exposure to earthquakes and hurricanes, etc., make unique public health problems. Sanitary control of the tropics has been remarkably demonstrated, as in Jamaica, Havana, Puerto Rico and elsewhere. The control of sanitation and disease hazards, together with the peculiar local climatic advantages of many parts, makes these islands of importance as health resorts and as areas of permanent settlement by the white race.

Little need be added with reference to the Caribbean coast of Central America, where is found an extension southward below Yucatan of the narrow, hot, wet, coastal plain of Mexico. Honduras has a valuable frontage of 60 miles on the Bay of Fonseca on the Pacific, a deep harbor unsurpassed in the world. Several fine interior valleys provide reservoirs which feed the important rivers flowing into the Caribbean, many of which are navigable 60 or more miles inland. The largest of these is the Segovia. The Ulna River drains about one third of Honduras, rising in the remarkable plain of Comayagua, a great transverse valley, 40 miles in length and 15 miles wide at the most, out of which flow through broad valleys the Goascoran into the Pacific and the Humuya, a tributary of the Ulna, into the Caribbean. This low broad valley makes a natural pathway from the Atlantic to the Pacific. As throughout Central America, there are two seasons, a wet and dry, the latter from November to May. The interior highlands, with their fine valleys and lakes, have a delightful climate, at Tegucigalpa, the capital, the annual range being from 50 to 90 degrees.

In Guatemala the plain of Peten in

the north is worthy of special note. This plain is essentially a part of the Yucatan peninsula, is grass- or tree-covered, in many parts fertile and well watered, but is inhabited chiefly by a few Indians, averaging less than two per square mile. This contrasts with one of the thickest known jungles along the Motagua River. The malaria of the coasts is not prevalent elsewhere and the healthy interior has the usual salubrious climate of tropical highlands. Only the necessary seaports are on the coast. Rainfall ranges from 195 inches at Tual on the Caribbean to 27 inches and less in the interior. The population of Guatemala is of special medical interest because of the low death rate and high birth rate, leading to a rapid increase. Guatemala contains about one third of the population of Central America. Three fifths of these are pure Indians, indolent, unthrifty and addicted to gambling. Of the remainder, pure whites are a small minority among the mestizos. The numerous Italian colonists are looked down on by the Indians because of their industry and thrift. Half the Indian births and one third of the white births are illegitimate. Alcoholism is prevalent among the Indians, whose chief diet is of corn, beans and bananas, with occasional fresh pork. The lack of development and the backwardness of Guatemala, rich as she is, are due to the political insecurity and to numerous and dangerous earthquakes, both of which interfere with capital investment and advance of civilization. Guatemala City, the capital, was destroyed by earthquake in 1918. German colonists before the Great War controlled most of the plantations and half the exports of coffee were to Germany. Guatemala is surpassed in coffee production only by the East Indies and Brazil. (Encyc. Brit., XI).

Costa Rica also has a high tableland, cut by lofty ranges, descending precipitously to the Pacific and more grad-

ually to the Caribbean, the latter shore being low, sandy in places, with marshes and lagoons and no harbor. The proximity of the two oceans make the climate variable, but the three great belts of hot, temperate and cool climate can be traced here also according to altitude. The rainy season, from April to December, has a strange interruption of two or three weeks of drouth in June, called the Veranillo de San Juan. In general, it is remarkably healthy for a tropical land, malaria and rheumatism in the lower levels being most prevalent. The population has a higher percentage of Spanish blood than elsewhere in Central America, and the black admixture is extremely small. Earthquakes, landslides and cloudbursts are its great natural enemies. Its great human asset is its relative political security and freedom from revolutions, largely a result of the considerable number of landed peasant proprietors.

Nicaragua has a Caribbean coast-line of 300 miles, which is low, swampy and exhibits the worst features of tropical climate. All its rivers empty into the Caribbean Sea. While there is a crowded galaxy of volcanoes along the Pacific, earthquakes are less severe than in the countries to the northward. This is compensation to some extent for its lying in the Papagayos tornado belt. Its predominant interest lies in Lake Nicaragua, a hundred miles long and forty-five wide, lying at high water 110 feet above sea-level. The influence of the trade winds causes a curious rise and fall on this lake, which for a time was thought to be a tide. Lake Nicaragua, with its valleys leading to the two oceans, is the third natural roadway between the Pacific and Atlantic, and ranks next to the Panaman Isthmus in importance. The two other roadways are at Tehuantepec and the Honduran plain of Comayagua. Bluefields, named after the Dutch corsair, Blieveldt, and

Greytown are the chief Caribbean ports for the interior and Managua, the capital. The uplands of the interior are healthy, in spite of a generally heavy rainfall, often exceeding 100 inches and at Greytown on the coast approaching 300 inches. Bizarre racial blends are common among the people, Indians with fair skin and blue eyes being seen along with others having Indian or Negro coloring and European features. With practically no immigration, the population is yet increasing rapidly. Nowhere on the American continents have revolutions and political upheavals been as frequent as in Nicaragua. For 225 miles the Caribbean coast of Nicaragua is known as the Mosquito Coast, from the name of the chief inhabitants, the Misskito Indians. After a more or less independent existence as a protectorate of England, from its first colonization in 1630, this territory in 1804 became a province of Nicaragua.

Only a few points need to be noted with reference to Panama, including the ten-mile strip of the Canal Zone. Panama is 41 to 118 miles in width, with a length of 430 miles. Low mountains, the meeting of the Pacific trade winds with the winds from the Caribbean leading to heavy rainfall, and the wide-spread jungles and forests, with an irregular broken hinterland, are of importance. Numerous islands, over a thousand in number, are found off the coasts. While there has been no volcanic activity within historic times and apparently not since the Pliocene Tertiary age, earthquakes are frequent and severe, except in the region of the Canal Zone.

PANAMA CANAL

For detailed description of the Canal Zone with its special problems of sanitation, hygiene and quarantine, reference must be made to numerous special volumes and articles. We can review here only the general features. The canal is

really a huge water-bridge across the isthmus, 85 feet above sea level, entered by locks at either end, and fortified heavily. It is a United States military post, and non-military use of land within the 10-mile Zone and its approaches is under revocable licenses by the government to steamship companies and planters. The canal was built within a period of ten years, of which the first three were occupied with extensive preparations, of which the chief were sanitation and disease control within the Zone. This included provision of pure water supply to the Zone, including the towns of Colon and Panama; adequate sewage disposal, food supplies and living quarters; complete drainage and mosquito eradication over a belt much wider than the Zone, with eradication of yellow fever and malaria, and the control of all other transmissible diseases.

The canal was constructed by a commission, consisting of four army engineers, an army physician, one navy engineer and one civilian. Of these Colonel Goethals was made chief executive with supreme civil and military power in the Canal Zone. The task of sanitation, disease prevention and eradication and all medical supervision was not exceeded if equalled by any other department of the work, in its fundamental value for the success of the project. Disease had invariably defeated its human antagonist disastrously in the nearly 400 years of effort to connect these oceans. Due to the skill and executive ability of the army physician on the Canal Commission, utilizing to the full the knowledge and experience of tropical medicine won, in no small part, by American physicians, the sanitary foundation was laid on which the canal was built. It is no exaggeration to compare the human service and value of the Panama Canal with that of the Suez Canal. At Suez the total cost was under ninety millions of dollars. At

Panama nearly three hundred and sixty-seven millions were expended, not including cost of military defense. Tropical medical science paved the way for success, a medical exploit worthy to rank with that of Henry R. Carter and the Yellow Fever Commission, as shining lights in the world's progress toward disease control. The army physician, in whom were so admirably focussed the capabilities of modern medicine and American executive genius, was Major General William C. Gorgas, later surgeon-general of the United States Army.

The medical problems at Panama were met fully and efficiently. They consisted of (a) protection of the working force, which averaged 39,000 men, against local communicable diseases; (b) care of sick and injured, not only among employees, but in Panaman population and from adjacent countries; (c) quarantine to prevent introduction of communicable diseases from other countries; (d) quarantine to prevent passing on communicable diseases to other countries from this cross-roads and pathologic mixing pot of the Americas; (e) research on problems of practical importance in the Canal Zone and general investigations favored by the abundant clinical and pathologic material available. The greatest disease enemies were yellow fever and malaria. Mosquito control and even eradication, by drainage, clearing brush and screening of houses and patients, wiped out the former and reduced the latter to a minimum. Fears as to the sanitary effect of new transport facilities through the canal between the Atlantic and Pacific have not been realized. In fact the quarantine control has become a world model, has facilitated shipping and has been a powerful agent in cleaning up disease foci in the tropical Americas in general.

CARIBBEAN COAST OF SOUTH AMERICA

The Caribbean Sea washes the tropical shores of South America from Panama to the island of Trinidad, off the eastern coast of Venezuela. Colombia, from which Panama revolted in 1903, is backward socially and difficultly accessible topographically. Lying across the equator, its southern edge rests in the forested Amazonian watershed. North of this the tributaries of the Orinoco have their origin. Here the llanos have a two season climate, a heavy wet season and a drouth-like dry season, both with high temperature. From the Arctic bleakness of the Cordilleran heights, change of altitude alone is sufficient in practically the same latitudes, to produce the wet, hot climate of the Caribbean Coast and the Magdalena River valley. Cooling winds are cut off here by mountains. The rain and heat of the coast, with the marshes and jungle, make it extremely unhealthy. The population shows two features of special note. (1) About one third is made up of Negroes and Negro mixtures. (2) One tenth is classed as white and consists chiefly of the descendants of Spanish colonists. Climate and the lure of gold have sent them into the interior altitudes, where they are still found, nearly unchanged from their ancestors, isolated, and only with small port colonies in the lowlands to give a meager communication with Spain. A. J. Lamoureux says: "The isolation of these inland settlements has served to preserve the language, manners and physical characteristics of these early colonists with less variation than in any other Spanish-American state. They form an intelligent, high-spirited class of people; with all the defects and virtues of their ancestry." Politically, Colombia is much harassed, like her neighbors, by changing régimes. So-

cially, she suffers for lack of a fair educational system, in spite of the traditional atmosphere of culture at Bogota. Economically her chief wealth is still from her mines, though pastoral industries are of some importance in the interior, and fruit raising, stimulated by American requirements, is rapidly increasing in the lowlands.

The coast of Venezuela is humid but relatively cool, due to the trade winds. About four fifths of the country is contained in the system of the Orinoco River and here one found wide-spreading grass plains, with low forests and shrubbery in places, and a dry climate hotter than on the coast. As in Colombia there is a large Negro mixture in the population and about 79 per cent. of the total are mixed breeds of some type. The climate is generally healthy wherever the coast trade winds penetrate, very hot and enervating elsewhere, and disease hazards are as much due to poor sanitation as to climate. In colonial times the inland plains, the llanos, pastured huge herds whose disappearance with successive wars has left the country a desert. Settled polities will lead to an enormous development of these fertile plains.

AMAZON AND ORINOCO VALLEYS

From the island of Trinidad eastward a large part of the South American coast is occupied by the great valleys of the Amazon and Orinoco rivers. The Orinoco basin is almost entirely comprehended in Venezuela. Between its mouth and the outlets of the Amazon in Brazil is a small coast district, including British, Dutch and French Guiana. The Guianas share in the general character of the Caribbean littoral. There is a wide rich alluvial zone 18 to 50 miles in width, leading back to low plateau country largely covered with heavy jungle and containing the famous gold deposits. This zone gives way in the hinterland to savannahs and grassy

plains, which rise into mountains, some of which are heavily forested. These colonies are distinguished by their rivers, which are numerous, and, as is so frequent in the Orinoco and Amazon basins, have many inter-connections. Tuberculosis is especially prevalent because of primitive sanitary ideas, and malaria of course is wide-spread. Hurricanes and heavy storms are unknown. The character of the coast makes tidal waves impossible and earthquakes harmless. French Guiana (Cayenne) has long had a French penal settlement and has furnished a site of exile for political and other offenders.

The rich valley of the Orinoco has today fewer inhabitants than in the time of its discovery 400 years ago. Its chief settlement is Ciudad Bolivar, 373 miles from the mouth. Its forest- and jungle-covered upper reaches are to a considerable degree unexplored.

The great River Amazon has a drainage basin of 2,720,000 square miles, which covers two fifths of South America. For its lower 400 miles, up to the straits of Obidos, it is merely a deep ocean gulf. It seems to consist of long level stretches with short inclines having very slight fall. The huge flood rise of fifty feet or more each year leads to two peculiarities. (1) It furnishes sufficient head from the great tributaries such as the Madeira and Negro, to carry the vast quantity of water to the Atlantic in a heavy current, through a mouth 160 miles in actual width. (2) It results in the peculiar and characteristic phenomenon of a huge flood plain, several hundreds of thousands of square miles in area, which is rarely more than fifteen feet higher than low water level, and which is inundated and cut up into numerous islands with connecting canals, water-courses and even new river channels, forming a tremendously complex topography, and which was a chief obstacle to navigation and exploration. An example of the peculiar channel re-

lations of this river system is seen in the natural Casiquiare Canal, which connects the Rio Negro, the great northern tributary of the Amazon, by a broad waterway, elevated some 300 feet above sea-level, with the Orinoco. Its origin in the Orinoco is about 300 feet in width, and its mouth in the Rio Negro is 1,750 feet wide. It is a major wonder of the world, unique and almost unbelievable.

The combat between the Atlantic tides and the discharge of the Amazon at its mouth results in the great Pororoca, or bore, a wall of water five to twelve feet high which rushes over the sandy shores and half-submerged islands at a speed of ten to fifteen miles per hour. This explains why the huge load of silt is carried far to sea and the river forms no delta, rather yielding coast-line to the Atlantic. The Amazon can be considered a tremendous reservoir, into which empty fourteen large rivers and an innumerable number of smaller ones.

The chief settlements are Para, just south of the mouth; Manaos, at the junction of the Negro, and Iquitos, in Peru. Navigation is rapidly increasing with several commercial lines running regular schedules and numerous small and local steamers. The population of the basin is relatively very small. Conditions of flooding, tropical jungles over the lowlands, intolerable insect pests, equatorial heat and high incidence of malaria and numerous other diseases have thus far prevented colonization and even exploration. The great immediate obstacle to development is the lack of food supply. After 400 years, not above 25 square miles are under cultivation. The scattered areas of settlement and development on the distant mountain headwaters are practically inaccessible.

The tropical lowlands of South America are seen characteristically in the Amazon valley. Nowhere in the world

is plant life more luxuriant or varied. Here is the native home of several rubber plants, cotton, potato, tomato, manioc, pineapple, maize, cinchona, ipecac, coca, vegetable ivory, chocolate plant, Paraguayan tea. Palms are the outstanding feature of the vegetation, occurring in a great variety of forms. Bamboos and an endless variety of ferns combine to make a floral richness nowhere equalled. Bananas, coffee, sugar-cane and oranges have been introduced and grow luxuriantly. The forests are rarely limited to few species, but everywhere show great diversity, beauty and commercial richness.

The wealth of the Amazon to-day lies solely in native forest products, chiefly rubber. The iniquities of rubber collection in the Amazonian forests, the cruelty and brutality with which the Indians have been treated and the enormous difficulties of climate, disease and transportation have been described elsewhere and can not be exaggerated. The collapse of the rubber market in 1915, with the introduction of cultivated East Indian rubber, forced the inhabitants to turn abruptly to fishing and the cultivation of manioc, cane, corn, tobacco and nuts. Since 1910 commercial development has been extensive. The Madeira-Mamoré railroad, 220 miles in length, has opened a huge virgin territory, radio and telegraph have reduced the isolation, and several thriving towns have developed outside of the principal ports of Para, Manaos and Iquitos. Imports are increasing and population is growing. Para has about 180,000; Manaos, 40,000; Iquitos, 8,000; Seuitarrem, 5,000, and Obidos, 3,000. Of the million and a half inhabitants of the Amazon valley, not over 200,000 live outside of Brazil. In exploration special mention should be made of the expedition of the American Rubber Commission—financed by the United States Government, and including ex-

perts from Brazil, Peru and Bolivia. Surveys were made on thirty-seven major water courses, with analyses of soil, climate, topography and especially suitability for cultivation of rubber and sugar-cane. Modern explorations of great value were made by the Roosevelt Expedition in 1913-14, the Fleming Expedition in 1919 and the Rice Expedition in 1924, as well as numerous smaller and more limited expeditions. It must be remembered that huge areas of Amazonia are unexplored; that the Indians of the forests are largely unknown, even with the advanced policy of conciliation of the Brazilian government; that extreme heat, humidity and impenetrable jungle combine with the savagery of the natives to make exploration difficult; and that the problem of local food supply and maintaining a foothold against the jungle is nearly insurmountable at present. It is a country of strange and grotesque phenomena; of vampires, small poisonous snakes and large crushing reptiles; of cannibals and head hunters; of strange poisons, blow-guns, dwarfs, giants, white Indians; of plants having weird properties like the *yáge*, which is said to release the subconscious mind; of strange occult rites, terrible and bizarre, like those of *juripuri*; of unknown intoxicating drinks; of countless hordes of insect pests, mosquitoes, sand-flies, jiggers, biting flies and numerous others. Beriberi is naturally sequent to the prevailing native dietary, while malignant malaria and black-water fever are forever lying in wait.

Among the great problems of tropical medicine is the question of the availability of Amazonia for civilized human culture. It comprises the largest fertile, nearly vacant and unexplored area in the world to-day. Its productivity and richness are practically inexhaustible. The obstacles to its development are the flood conditions, climate, insect life and overpowering jungle forest growth already noted. Development here means

primarily agriculture. Agriculture will depend primarily on medical control of disease conditions. The problem of permanent white colonization is discussed elsewhere. Future human food supplies are of paramount importance for future civilization. What has scientific medicine to offer for the control and development of this tremendous, rich empire of the tropics, now virtually lying fallow?

EASTERN SOUTH AMERICA

Outside the Amazon, the chief river of Brazil is the São Francisco, entering the Atlantic well south of Cape Rogue, after a course through hilly and low mountainous country. The water system entering the Atlantic through the Plata estuary includes the Uruguay which parallels the coast and bounds on the west Uruguay and the southernmost state of Brazil; and the Paraguay and Paraná Rivers, which communicate with headwaters of the Amazon in the Brazilian Andes of Mato Grosso, Goyaz and Minas Geraes. The upper courses of this system are in tropical country, gradually becoming continuous with the Amazon basin. The upper Paraguay winds sluggishly across wide grass-plains dotted with palms and occasional peaks. Huge areas of inland plain, like the Gran Chaco in northern Paraguay and Argentine, are wet and covered with heavy vegetation. Disease conditions and native population are similar to those on the Amazon.

In the tropical area of the east coast is found the great coffee port of Santos with an excellent deep harbor. The heavy vegetation, swamps and great heat and rainfall of Santos have made it an endemic home for malaria, rheumatism, dysenteries, smallpox, beriberi and many other diseases. Plague has appeared since 1900 also. Good drainage has now made the city itself fairly healthful, and conditions are improving with a general policy of sanitation and drainage. Fifty miles northwest of

Santos is the fine city of São Paulo, connected with its port of Santos by a double-track railway. São Paulo, the "Heart of Coffee-land," lies at two to three thousand feet elevation on an inland plain, part of the city, however, being along the unhealthy alluvial bed of the Tiete River. Except for this portion, its altitude gives it a bracing climate with hot sun temperatures. It is a rich city and decidedly healthy in spite of poor sanitation. Its population is about 650,000. About ten miles from the city is the governmental snake farm, the Instituto Butantan, of world-wide reputation, where experimental work and anti-venin manufacture are carried on together.

Rio de Janeiro needs no additional description. The fight against the mosquito, the measures of disease control, the harbor, unequalled in beauty and natural adaptability, make it justly famed. Here is found the splendid Oswaldo Cruz Institute, named for its founder, who eradicated yellow fever and plague from Rio and was the pioneer in the system of sanitation and medical control which is already making substantial inroads on the disease problems of the Brazilian tropics. One third of the expense of maintenance is borne by the government. It is a model of its kind and ranks among the world centers for study of tropical medicine. Rio, São Paulo and Santos are important and up-to-date medical centers and for the student of tropical medicine furnish remarkable illustrations of what scientific medicine can accomplish in a tropical climate, with a race blended between Latins, Indians and Negroes. The Negro finds his greatest opportunity in Brazil, and in every respect is on equal footing, according to his individual capacities. Italian immigration is an important and valuable factor. With the native wealth of the country, the unusual blend of tropically acclimated races with an infusion of northern blood

and a vigorous sense of nationality and of scientific values, the future of Brazil as a great tropical power is absolutely unlimited and unvisionable.

PLATEAU AND MOUNTAIN BELT

In the Andes are found the most tremendous mountains of the western hemisphere, culminating in Mount Aconcagua in Argentina, 23,080 feet in height. The western slope is abrupt and in South America apt to be barren and cool. The eastern slopes are more gradual and give rise to the huge system of rivers already described. Two points of medical interest are to be noted. (1) The peculiar isolation of certain valleys of the northwestern Andes, as in Colombia and near Lima, where Oroya fever and verruga are prevalent. (2) The remarkably fine climate in the upland plateau regions, where altitude, moderate rainfall and absence of excessive humidity, combined with hot sun temperatures, give an unusually fine physical environment. These regions are contiguous to and often easily accessible from the hot disease-infested coastal and river lowlands.

PACIFIC COASTAL PLAIN

The Pacific coastal plain is narrow, averaging some forty miles in width. From about 30 degrees south latitude to Guayaquil, just below the equator in Ecuador, it is barren, in many places, sandy, dry and cooled by the Antarctic current. Short inconstant rivers cross at intervals, but the ancient irrigation systems have not been adequately replaced or extended. Development waits on irrigation. From Guayaquil to Panama, tropical vegetation is found, with its accompanying heat and humidity. This continues largely through Central America, where Salvador is especially noted for its large variety of native medicinal plants. In Mexico, the region of the Pacific calms, the so-called "horse latitudes," gives a hot dry climate merging virtually into a desert on

the low coasts of Sonora and Lower California. Many rivers cross this area but are not utilized for irrigation. This dry hot climate extends over the high plains and deserts of northwestern Mexico and includes the southern portion of the southwestern United States.

MEDICAL CONSIDERATIONS

South America is preeminently the land where racial mixtures can be studied almost as in a laboratory. Already it has proved that color is no barrier to racial intermixture. There is no race problem in the southern continent in the sense of a color or race line drawn socially and politically. Mixed bloods always rank with the higher type, whether Indian or Negro. Of the entire habitable and productive earth, South America has relatively the lowest population. It is therefore the last reserve area into which humanity will pour by immigration for settlement and commercially for exploitation and productive development. Like Africa, South America looks to the east and is influ-

enced intimately by Europe, especially France. German and Italian immigration is important and brings to racial mixtures valuable additions. Political instability, with the lethargy and passivity of the Indian population, militate strongly against adequate and continuous public health programs. Climatic effects and wide-spread disease conditions, such as hookworm, venereal, tuberculous and malarial infections, have a definite influence in reducing initiative and interfering with development of a public conscience. The three elements which especially tend to make for backward health conditions are (1) the racial character of the population in the various countries of the American tropical zone, (2) true climatic factors, and (3) incidence of chronic debilitating diseases and defective nutrition. It is a question as to how much political instability is also secondary to these factors. As so often in human affairs, medical conditions in the broad sense are fundamental for human advancement.

VIRUS DISEASES OF PLANTS

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ABOUT 1868, a remarkable plant, which was said to have originated in the West Indies, appeared on the European markets. It belonged to the genus *Abutilon* and was remarkable for two reasons. First, it had very beautiful, variegated foliage; and second, this character was not transmitted through the seeds, which produced plants with green foliage. But these beautiful variegations could be transmitted by budding or grafting scions from variegated plants to green plants. Furthermore, the green shoots of various other Malvaceous plants which had been grafted with variegated scions frequently developed foliage of the same kind, indicating that this character was transmitted in some unknown manner through the sap from the variegated scion into the green branch. These ornamental plants became very popular and were sold under the names of "variegated maples" and "Chinese bell flowers," but no one suspected that the mottlings were symptoms of a disease and that this was the first important step in the study of a group of maladies which are now known as "virus diseases."

This was not the first virus disease to attract attention, but the fact that it could be perpetuated by grafting and not by seeds marks an epoch in the history of these maladies. Many irregularities in plant growths which we now recognize as virus diseases had been noted for centuries. One of the most interesting of these is a disease of tulips, known as "breaking," which causes the infected flowers to develop beautiful variegations in colors. The earliest records of this disease are pictures of about

1640 to 1650. It was recognized, many years ago, that these variegated tulips were less vigorous than the ordinary plants, and it was assumed that this beauty was the result of the final efforts of the plants to express their gratitude for the care and attention which they had received from the growers. "The Gardener's Dictionary" (1758) contains a very interesting discussion on this subject which reads as follows:

This alternation in the Colour of these Flowers may be seen long before they are blown, for all the green Leaves of the Plant will appear of a fainter Colour, and seem to be striped with white, or of a brownish Colour, which is a plain Proof, that the Juices of the whole Plant are altered, or, at least, the Vessels through which the Juice is strained; so that hereby Particles of a different Figure are capable of passing through them, which when entered into the Petals of the Flower, reflect the Rays of Light in a different Manner, which occasions the Variety we see in the Colours of Flowers (but this is more fully explained in the Article VEGETATION; which see). This breaking of the Colours in Flowers proceeds from Weakness, or at least is the Cause of Weakness in Plants; for it is observable that after Tulips are broken into fine Stripes, they never grow so tall as before, nor are the Stems, Leaves, or Flowers, so large, and it is the same in all other variegated Plants and Flowers whatever, which are also much tenderer than they were before they were striped; so that many Sorts of exotic Plants, which by Accident became variegated in their Leaves, are often rendered so tender, as not to be preserved without much more Care, though indeed the stripes of Tulips doth never occasion so great Weakness in them as to render them very tender. The greatest Effect it hath on them, is in lessening their Growth, causing some (which, while they continue in their original plain Colours, did rise near three Feet in Height) to advance little more than two after their Colours were altered; and the more beautifully their Stripes appear, the shorter will be their Stems, and the weaker their Flowers.

Within the last few years, it has been demonstrated that the beautiful variegations in "broken tulips," which have attracted attention for so many years, are the symptoms of a virus disease.

A disease, similar in character, which has been known in tobacco for many years, was finally recognized as injurious and was the subject of an important paper (1886) by Mayer, who gave it the name of "mosaikkrankheit." The equivalent—mosaic—has been very generally accepted for a number of mottling diseases by the English and American students. This was the first important scientific paper on a virus disease in plants and may be looked upon as the starting point in our studies of this subject. This was followed two years later by an extensive bulletin on peach yellows by the late Dr. Erwin F. Smith. This disease had been known in America since 1791 and had been attributed to many causes, but the true cause was not demonstrated until many years later. Although Dr. Smith did not learn the cause of this disease, he learned many important facts which have been of great value to later students.

Extensive studies since the beginning of the present century have called our attention to mosaic diseases of many species of plants, and a large number of plant diseases, such as little peach, peach rosette, ring spot of tobacco, curly top of sugar beets, bunchy top of bananas, etc., all of which possess certain characters in common. Recent studies have resulted in their being classified in one common group known as "virus diseases."

Many of these diseases are the causes of very heavy losses in our agricultural crops. A disease of potatoes, which was known in England by the name of "curl" as early as 1757, was recognized as an important factor in the reduction of the crops. We now recognize several virus diseases of potatoes which cause

losses. The virus diseases of sugar-cane, sugar beets, peaches, potatoes, tomatoes and tobacco are well-known causes of heavy losses, both in actual crop production and in the use of methods for their control.

In 1892 Iwanowski reported a discovery which was of much greater importance than he realized, a discovery which was destined to revolutionize the study of many diseases of both plants and animals. He found that the active agent which caused the mosaic of tobacco would pass through a filter that was fine enough to remove bacteria. Six years later (1898), Beijerinck confirmed the work of Iwanowski. In this same year, Loeffler and Frosch in Germany discovered that the active agent of the foot and mouth disease would pass through a porcelain filter. This was followed by the discovery that the active agents of many diseases of both plants and animals would pass through bacterial filters and retain the power of transmitting disease. Eventually these maladies became known as filterable "virus diseases" and are now recognized as among the most important branches of plant and animal diseases. Many of these filterable virus diseases have been recognized and the symptoms described. A very large number of trained men and women have been and are employed in the studies of these maladies and an extensive literature has been published.

The causal agents of these diseases have attracted the attention of research students from the first. Mayer believed that the mosaic of tobacco was caused by bacteria, and this theory was supported by Iwanowski and others and has some adherents at the present time. This was a very reasonable theory, because the new branch of science known as bacteriology, which had developed as a result of the work of Pasteur, had explained so many phenomena which were

not understood previously. Mayer believed that the bacteria were transmitted in the soil, and Iwanowski believed that at certain periods in their development they were small enough to pass through a bacterial filter.

Beijerinck (1898) rejected the bacterial theory and advanced the theory that the active agent was a living fluid, which was parasitic in the cells of the host plant, and gave it the name "*contagium virum fluidum*." This was followed very quickly by the enzyme theory, which was advanced in 1899 by Woods in America and by Heintzel in Europe, working independently. Woods published three papers in which he expressed the belief that the mosaic disease of tobacco and some other plants resulted from an excessive accumulation of oxidizing enzymes, which prevented the normal production of chlorophyll and caused a partial starvation of the plants. He was probably influenced by the studies on enzymes which were attracting so much attention and by the knowledge of the effects of oxidation on chlorophyll. This theory was very favorably received by a large number of workers and still has a considerable number of supporters.

The next important theory was that protozoa were the causal agents, based on the fact that protozoa-like bodies have been seen in the cells of many plants infected with virus diseases. Iwanowski (1903)¹ was the first to report these bodies. He found them in the cells of mosaic tobacco plants but believed them to be the results of the disease rather than the cause. In 1910, Lyon, of Hawaii, reported plasmodia-like bodies in the cells of sugar-cane infected by Fiji disease, which was not at that time included in the virus diseases. In 1921, Kunkel reported the finding of intra-cellular or X-bodies in the cells of

mosaic corn and suggested that they might be the cause of the disease. These bodies were strikingly similar to those described for tobacco by Iwanowski in 1903. The work of Kunkel was followed by the finding of similar bodies in the cells of many plants infected with virus diseases. Many students believed that these bodies were the causal agents of these diseases, while others believed that they were the products of the diseased cells.

This was followed by the discovery of flagellate-like bodies in the cells of mosaic plants, and in December, 1922, Nelson read a paper before the American Phytopathological Society in which he reported the finding of bodies which he believed to be flagellates in the fibro-vascular bundles of several species of plants that were infected with virus diseases. Some confirmatory and much negative evidence has been advanced by workers in different parts of the world since that time. This was followed by the plasmodial theory, which was advanced by Jones, but which has not received much support.

Many other theories have been advanced from time to time, such as character of the soil, insects and other agencies. So much attention has been given to the studies of soils and fertilizers that this theory offered a most fertile field for unscrupulous commercial organizations and "quaeks" who had wonderful discoveries and patent processes for the cure of these diseases.

The filterable virus theory, which is the one most generally accepted at this time, can not be attributed to any one student of the subject. The name "virus" was used by many workers who were advocates of other theories and long before there was any definite grouping of these diseases as a result of the recognition of common characters. The original meaning of the word was liquid poison, but it was later applied

¹ In this same year Negri reported the finding of small bodies in the brain cells of animals attacked with rabies.

to the material used for vaccination for the prevention of smallpox and still later to designate the material used for the prevention of other diseases. It gradually came into its present use between 1915 and 1920 as a name for the active agents of certain diseases, most of which are known to pass through bacterial filters and retain the power to produce the diseases when inoculated into plants of the same species (and sometimes other species) from which they were obtained. This definition is not entirely correct, because it is well known that some bacteria will pass through a filter and because it is also well known that some of the virus diseases have not been transmitted by inoculation with either filtered or unfiltered juices of plants, but have been transmitted by grafting or budding. But these diseases have so many characters in common that we believe that we are justified in classifying them in the same general group.

The properties of the active agents may be described as follows: (1) They are infectious; (2) they are present in nearly all parts of the infected plants, but are rarely transmitted through the seeds; (3) they increase in quantity within the plants; (4) in most cases they will pass through filters that retain bacteria; (5) very small quantities and very great dilutions of juices from infected plants will transmit many of these diseases; (6) they are influenced by changes in temperature and can not live beyond certain ranges; (7) they are modified and killed by certain chemicals; (8) some of them become attenuated as a result of transmission through resistant plants; (9) they are influenced to some extent by light; (10) a very few workers claim to have grown them in cultures.

The transmission of these diseases from plant to plant is a factor that has attracted the attention of the students

from the very first. The variegations of *Abutilon thompsoni* (1868) were transmitted by grafting long before this character was recognized as a symptom of disease. Smith (1888) reported that peach yellows could be transmitted by budding, and since that time it has been demonstrated that a very large number of these diseases can be transmitted by this method. Mayer (1886) reported that the mosaic of tobacco could be produced by inoculating a healthy plant with the juice from a diseased plant. Later workers believed this disease could be transmitted by mere contact between diseased and healthy plants or by merely touching a diseased and then a healthy plant, and it was demonstrated that the field laborers were frequently responsible for its spread in the fields. In 1917 Allard reported that the common tobacco mosaic of America could not be transmitted in this manner unless the healthy plant had been injured, although a very slight breaking of the plant hairs was sufficient for the entrance of the active agent. It is now known that many of these diseases can be transmitted by the inoculation of healthy plants with the juices from diseased plants and that field laborers are responsible for the spread of some of them. Transmission by vegetative parts, such as tubers, bulbs, roots and cuttings, is recognized in a large number of species of plants. Transmission by pollen has not been demonstrated, but transmission by seeds, although not general, has been demonstrated for a number of plants.

One of the most remarkable, interesting and important phenomena of these diseases is the transmission by means of insects. Woods called attention to aphids which were associated with the Bermuda lily disease in 1897 and to stigmoneose of carnations in 1900, but it was not known at that time that these diseases had anything in common with

what are now known as virus diseases. The first demonstration of a virus disease by means of an insect was the curly top of sugar beet by the leaf hopper (*Eutetix tenella*) in 1906. No one at that time knew that curly top was a malady with properties more or less in common with many other diseases that are now grouped under the common name of "filterable virus diseases," and Ball, who performed the first experiment, believed that curly top was caused by the insects. In 1910, Shaw reported the results of experiments which demonstrated that the disease could be produced by leaf-hoppers which had fed on

curly top beets in the Southwest and then been carried to Washington, D. C., where they were put into cages with healthy plants. He did not succeed in producing the disease in any other manner. The work of these two men led to extensive studies by other workers, who have demonstrated during the last two decades that a very large number of these diseases are carried from plant to plant by insects.

The virus diseases of plants are now recognized as constituting one of the most important fields of study in plant growth and one of the most important branches of plant pathology.

MACRO-CEPHALISM

By Professor L. M. PASSANO

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EDMUND SPENSER, in "The Ruines of Time," tells the reader to

Looke backe, who list, unto the former ages,
And call to count what is of them become:

and asks, like many another poet, the question:

Where be those learned wits and antique Sages,
Which of all wisedome knew the perfect somme?

The answer is, of course, that they have taken a back seat; the seats of the mighty being now filled by the "great scientist" and the "big business man."

The substitution is both reasonable and just. In former ages, when there was an aristocracy of birth, there was naturally also an aristocracy of learning; men had leisure to think, men had leisure to learn, men had leisure to live, men had leisure even to dream. Possessions, if the "antique Sages" had them, were a means for enlarging and beautifying life, for expanding the realm of the spirit and extending the reaches of learning. But with the rise of the middle class with its "philosophy of

possessions as a sign of worth," that what a man has, he is; the doctrine that possessions "are nine points of the law" and ten points of the remainder of life; with all these things came the rise of an aristocracy, so-called, of wealth, and the decadence of the sages who, while they had a knowledge of possessions and their power, preferred the wisdom of simplicity and its worth.

In a way this reversal of society makes for simplification, not of life but of classification. What a man has, he is; and what he has follows the income tax returns. So that a man is placed, and, barring death and "depressions," remains fixed. Then the privileges, in signia and regalia of his social class are known, so that, as a self-appointed authority on social usage has declared, "no man with less than \$5,000 a year may carry a walking stick," and, possibly, not less than \$10,000 a year will confer the privilege of wearing spats.

These details, however, are of less interest and importance than the general idea of the replacement of the humanist

by the scientist. This replacement has been, of course, an evolution, not a revolution; and in this connection it is well to emphasize that evolution is not necessarily good any more than revolution is necessarily evil. The displaced humanist, whether Latinist or Hellenist, at the height of his renown was, strange as it may sound, human. He bowed down before the gods of necessity in order to live for better things, but never in real worship. His successor, the scientist, also is human and bows down before the gods of riches in that sincerest worship which expects as a return to share in the gifts of his gods, though it is true so far that, like Lazarus, he has had to be content with the crumbs that fall from the rich man's table.

There was a time when the scientist was modest. Indeed, it is only within the most recent years that he has attained to his present place, the footstools before the thrones of the truly great and wealthy, and his success illustrates a curious phase of evolution in which a new disease, bacterium or bug attacks a species, of which those only survive who are fit.

The disease, which may be called "macrocephalism," had for some time been prevalent in big-business circles. Its incidence was wide-spread but the death rate small. At about the time of the world war the contagion spread to the chemists who, by their researches into the deadly instruments of war, ammunition, poison gas, etc., had been thrown in contact with the makers of such things, thus helping to intensify the horror of war and to enrich themselves. Amongst the chemists after the war the disease became much less virulent, partly because the unfit had succumbed, partly because an attack of the disease renders one partially immune to further attacks.

In the meantime the chemist and physicist, finding they had many things

in common, had begun to fraternize and to banquet each other after the manner of the Fox and the Crane. Thus the contagion spread to the physicists, and amongst them the epidemic is now raging at its height. The great private and corporate industrial laboratories, established *ad majorem*—is it *scientiae* or *pecuniae gloriae*?—over whose portals is written in letters of gold two cubits tall the magic word "Service," have become like hospitals where all the patients have the same disease, and even the laboratories of our institutions of learning contain cases, more than sporadic, of macrocephalism.

The most interesting and remarkable symptom of macrocephalism is that it causes the patient to know—or to think he knows—everything. This symptom seems to be much more prevalent among the physicists than among the chemists, in this respect putting them almost on a par with the big business cases where the symptom is universal. Under the influence of the disease the patient will undertake the solution of every problem of science, economics, politics or finance; he will fix the place, if it have any place, of art in the social life of man; he will produce the perfect and universal system of morals; he will even reconcile science and religion, making of "science itself a philosophy of life and a justification of religion, as though the nescience of the physicist was the certainty of the theologian." All of which would be very comforting to mankind were it not that all the solutions, all the reconciliations are infused with the vagueness, the vacuity, of a mind working under the influence of disease.

Efforts to treat the disease have met with little success. Dr. Astronomy, with his mysticism, and Dr. Biology, with his materialism, have so far succeeded only in catching the disease themselves—in a somewhat mild form, since their opportunities for service are rather limited. The only treatment in any degree help-

ful has been that of the mathematician, and this has been vitiated by the fact that it starts from an incorrect diagnosis and is almost exclusively based upon empiricism. It is also doubtful if the mathematician, as a specialist, has not been disposed to increase his fees by prolonging the cure. His principle seems to be "more of the same." If three dimensions won't do, give the patient four, or five, or any old number. Also he has experimented by varying the shape, or curvature, of the medicine goblet in which the dimensions are immersed. Indeed, with the help of the astronomer, he once made a sort of rubber goblet which expanded and contracted into the weirdest shapes as the patient swallowed his dimensions. The mathematician, except in rare cases, seems to be immune to macro-cephalism, but when he does get it he gets it bad.¹

But the allegory may now be left to bask on the banks of the Nile, for

The time has come
To talk of many things:
Of shoes—and ships—and sealing wax—
Of cabbages—and kings—

to talk, not as the "antique sages" did, of how many angels can dance on the point of a needle, but of how many electrons can jazz around a proton. But, after all, are not the two questions much the same? To the medieval philosophers, angels and devils were as real, as actual, as electrons and protons to the modern scientist, or as solid atoms and the ether to the scientists of Victorian days, or as gravity and force to the Newtonians. After all, these are but names given to things unseen and unknown except by what they do, by their effects. "Hast thou seen him ever anywhere," the elec-

¹ The latest bulletin from the sick room states that a new treatment has been begun by Dr. Mathematicus. Instead of an infusion of electrons and dimensions in space, an elixir of "The psi function of wave-mechanics" is being administered. The patient is doing as well as could be expected.

tron, the angel? "Ah, no," replies the scientist, "but I have seen his illuminated path." "Ah, no," replies the poet, "but his 'trailing clouds of glory' I have seen." Oh, names, names! Calling them angels and devils, the medieval philosopher thinks he understands and "explains"; calling them electrons and protons, the modern scientist "explains" and understands in quite the same way. This is no true knowledge, for only "by their fruits ye shall know them," and if names are the fruits of knowledge surely Beelzebub is as crystal clear as Parathoxy-phenyl-thio-carbamide, and no more terrifying. As Alice said of Jabberwocky, "It seems very pretty, but it's *rather* hard to understand!—Somehow it seems to fill my head with ideas —only I don't exactly know what they are!"

There may be some permanent, ultimate reality back of, beyond, man's knowledge. If so it is unknown to man and probably will be forever unknown. Reality to man is what he knows now and here. There was a time when the earth was—I do not say seemed—the cosmic center around which sun, moon, planets and stars revolved in crystalline spheres. There was a time when the sun was—I do not say seemed—the center around which the planets moved in circles and epicycles. To-day the planets move around the sun in ellipses, in a space of five dimensions, of which only four are in actual use, as part of a universe contracting and expanding like a huge, globular jelly-fish. To-morrow —? As Milton says:

He his fabric of the heav'ns
Hath left to their disputes, perhaps to move
His laughter at their quaint opinions wide.
Hereafter, when they come to model heav'n
And calculate the stars, how they will wield
The mighty frame, how build, unbuild, contrive,
To save appearances.

However modeled, however wielded, the heavens, the earth and the fulness

thereof thus got will be real. Reality for man is that which he conceives, invents, "now and here," so that the boasted progress of science is but a substitution; a substitution of new lamps for old. The new lamps are brighter and give more light, perhaps, but they lack the wonder-working power of the old. The new lamps guide us on our daily path, but the old lamps revealed and made real to us all the treasures and marvels of the universe save one—the rukh's egg of omnipotence.

There may be dissenting voices to what has been written, but to the assertion that, here and now, the world in which mankind lives is the world of *possessions*, there will be no dissent. There was a time when the scientist, like the humanist, lived in a world of his own; a world in which he strove for self-development through knowledge; but now he strives for aggrandizement through power. Then he studied nature in search of beauty and truth. Now he studies the stock market in search of possessions. He has pulled science down from her altars to make her the servant

of industrial expansion. He has become the right hand of the industrial body and hopes to become its head by "boring from within." He will probably succeed. He has learned the game. He has learned the value of advertisement and publicity, and makes full use of them. He is forming "fellowships of superscholars," intellectual super-chambers of commerce to guard the interests of his class. He is devising ways to "attract in large numbers to the academic life men of independent means," not an unheard of effort in the educational world but—try and do it against the current of scientists flowing into industry. He will succeed, but like the investors of 1929 he forgets that there is a debit side to the ledger. He will succeed, but he will lose what Lord Dunsany calls "that elusive thing that lies just beyond the limit to which Science has penetrated," and will feel (investors of '29 also please note) "all the bleak emptiness there is in the world when mystery has left it." But one thing he will not lose. He will still be one in the great fellowship of the macro-cephalists.

SCIENCE SERVICE RADIO TALKS

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URANIUM AS THE EARTH'S CLOCK

By Dr. ALOIS F. KOVARIK

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MAN has an inborn desire to learn. If this were not true, progress would indeed be slow. When an archeologist discovers some old grave, man the scientist and man the layman show great interest in the age of the grave, in the individual buried there and in the social conditions that may have existed when the occupant of the grave still was alive. For identical reasons man is interested in the age of our earth, on which he considers himself as the supreme master among the living things.

Now, when we talk of the age of anything, we must bear in mind two important things: the first is the starting point from which we measure the age and the second is the clock employed in the measurement of the time. For example, the age of an individual is usually measured from the date of his birth and the usual unit of time is the year. The conception of the year by some people is merely the time that elapses from any date on the calendar to the same date on the next new calendar; while to others it represents the time for the earth to complete its elliptic path around the sun. In either case the year represents the time that elapsed during the performance of a series of events and the next year will represent the time that will elapse in the performance of the same events.

Galileo, the great Italian physicist whose work placed science on an experimental basis, measured time in his experiments in two ways. In one method he utilized the periodic swing of a pendulum, which later in the hands of a Dutch physicist, Huygens, became the

basis of construction of our pendulum clocks. In the other method, Galileo used a large tank of water and allowed the water to flow out through a small faucet into a container. If a cup of water was so obtained it measured a definite time for that water to flow out, while two cups required twice as long a time and half a cup only one half the time. Therefore, by weighing the water so obtained during an experiment, he had a measure of the time that elapsed. This was Galileo's "clock," which served him admirably to discover some of the fundamental laws of mechanics.

Consequently, if we are concerned with the age of the earth we must first of all define our starting point and then look for some series of events which in their repetition will give us a "clock" to measure the time.

To the Latin poet and philosopher, Lucretius, the world began when poets began writing poems about their heroes; to the theologians the biblical world begins with the first generation recorded in the Old Testament and their unit of time is the generation of mankind. On the other hand, the biologist is interested in the time when life began on the earth; the seaman is interested in the time when oceans began; the geologist is interested to know when the first crust of earth was formed and the age of any subsequent formation; while the astronomer thinks of the probable separation of the earth from the sun, and the cosmologist philosophizes about the origin of the universe.

Certainly, all these so-called "worlds"

are interesting, but it must be clear to every one who gives them a little thought that their "ages" are very different. We shall concern ourselves with the geologist's problem and shall consider the "geologic age," *i.e.*, the time elapsed since the beginning of the oldest formation on the surface of the earth, and incidentally we shall give some thought to the age of any formation.

When any of these geological formations were produced, various minerals were also formed in them. These primary minerals are therefore as old as the respective formations in which they are found. Some of these minerals contain radium and other radioactive elements.

Radium, to most of us, is the best-known radioactive element. It possesses the fundamentally distinctive property of not remaining radium forever, but is, in fact, changing right before our eyes into another element, which likewise changes, and this goes on until the last radioactive element of this series, known as polonium, changes into a type of lead which is not radioactive, *i.e.*, it does not change.

Like any other element, radium is made up of atoms, and it is, of course, the atoms which change. An atom of any element is in fact a complicated arrangement of electrical particles and of energy; but in a radioactive atom the arrangement does not possess permanent equilibrium. Due to causes which as yet are not known to us from experiment, the equilibrium of a radioactive atom becomes at some time unstable, and then an explosion occurs during which either an electron or an alpha-particle (the latter, in fact, being the nucleus of a helium atom) is ejected and with it is also ejected some of the energy. What is left of the atom becomes reconstructed into an atom of the next element following it in the series.

Atoms of radium eject alpha particles when they disintegrate. By studying

these ejected particles and the various effects they produce, we learn various things about these atoms. We find, for example, that in the case of radium four atoms out of every ten thousand radium atoms undergo this change every year. The statement that 4 radium atoms out of every 10,000 radium atoms cease to exist as radium atoms every year, characterizes the radioactive element radium. When the statement of the law of radioactive disintegration is put in this form, probably, some of you will recall a similar law, namely, the one in connection with life statistics. There we find that approximately 15 people out of every thousand, considering all ages, die every year. In both cases we are stating that a certain percentage of the existing individuals (radium atoms or people) cease to exist every year. In the case of the people, imagine that births suddenly cease and that 15 out of every 1,000 of the 2 billions of the earth's inhabitants die every year. Then 30 million will die the first year and 1,970 million will be left. During the second year about 29½ million will die, leaving 1,940½ million to begin the third year, and so on, the number dying each year decreasing because this number is a definite percentage of those living, which number, however, is continually decreasing.

Now suppose a cemetery is started for these dead at the time the births ceased. If, after some years, but within the period that some people are still living, a stranger visited our earth and observed the number buried in the cemetery, observed the census of the living for that particular year and also the percentage of the living that died in a given time, could this stranger calculate how old the cemetery was?

If the same number died every year calculation would be one of simple arithmetic. Since it is the percentage of those living that remains constant, by our hypothesis, the problem is not so simple; yet it is only slightly more difficult.

Now, this is exactly the problem we have when we consider the age of the mineral, which age will also be the age of the geological formation in which the mineral is found.

We must now note, however, that a radium atom was formed from a uranium atom which has undergone several changes similar to that which the radium atom itself undergoes. Uranium also has a characteristic percentage representing the death rate of the uranium atoms. Stated in the same language as for the radium atoms or for the earth's inhabitants, it is that 15 uranium atoms out of every one hundred thousand million of uranium atoms disintegrate every year. Each one of these atoms disintegrating becomes at some time a radium atom and at some later time an atom of lead. The atoms of lead do not change and they may be looked upon as the "dead" ready for the cemetery.

Consequently, our radioactive mineral contains not only the uranium atoms which have not yet changed but also the dead atoms of uranium which are the atoms of lead. When a chemist analyzes the mineral and finds the amount of uranium and the amount of lead, he has really taken a census of the living and dead uranium atoms. If also we count the number of uranium atoms which died as such in a given amount of uranium by counting the number of signals sent out by these dying atoms—namely, the alpha particles ejected, there being one alpha particle for each atom dying—we obtain the percentage changing per year required to be used as our "clock" in measuring the time, the total time depending on this measure and on the number of the dead uranium-radium atoms and on the number of the still living uranium atoms.

In this method of deducing the age of minerals we use the "percentage" of the

uranium atoms existing at any time as the number disintegrating per year at that particular time as the clock registering the time. The accumulated lead has to be measured off by this clock, which then gives us the number of years during which the accumulation continued: *i.e.*, during which this clock was running—and this is the age of the mineral and of the formation from which the mineral came. This method is due to the late Bertram Borden Boltwood, of Yale.

Some radioactive minerals—in fact, most of them—contain thorium as well as uranium and radium. The thorium atoms undergo similar changes, having their own characteristic percentage changing per year and ultimately leaving the final atoms—the dead atoms of thorium—as atoms of another type of lead, each of which differs from the one obtained from the uranium in that its atomic weight is different. This atomic weight is a symbol by which one tells one type of lead atom from another. If in our cemetery we also buried, say dogs, and labelled the graves of humans by crosses and of dogs by columns, we could tell these apart and count them separately. The different atomic weights of these lead atoms make it likewise possible to get these different lead atoms counted separately.

When we apply our knowledge to the data obtained from the analysis of a uranium-radium mineral from Sinyaya Pala in Carelia, Russia, we deduce the age of the oldest radioactive mineral known and it comes out to be 1,852 million years. We can then say that the earth's crust is at least 1,852 million years old. Some minerals in Norway are found to give about 850 million years for their age, and therefore the formations in Norway are younger or of a later period.

WHAT BLOOD TELLS

By Dr. M. H. JACOBS

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IN the old romances, when a man sold his soul to the powers of darkness, it was customary for him to sign the agreement with his blood. In this way, presumably, he left upon the paper something that was a characteristic part of himself, and so made the contract more binding. This more or less instinctive belief that an individual is in some special way represented by his blood has found scientific support in recent years. By means of methods that have been developed chiefly since the beginning of the present century, a small sample of blood may now be made to yield a surprising amount of information about the individual from which it came.

The first thing that such a sample of blood tells is the kind of animal that supplied it. To the unaided human eye there are no very distinct differences between the bloods of the thirty or forty thousand known kinds of vertebrate animals. Nevertheless, it is possible not only to show that each of these kinds of blood is different from every other kind, but, if necessary, to identify a given sample. For this purpose a few drops are usually sufficient—indeed, sometimes a mere dried blood stain may be employed. This latter possibility has at times been put to practical use in murder trials. Suppose, for example, that in such a trial a bloodstained ax is offered as evidence. The prosecution claims that the blood is of human origin; the defense contends that it is that of a chicken. There should be no very serious difficulty in such a case in identifying the blood and possibly in this way in determining the outcome of the trial.

Some of the most delicate and precise methods of identifying blood require the use, not of ordinary chemical reagents,

but of blood itself. For example, a rabbit by the proper technique is given several doses of human blood. Its own blood is changed by this treatment in such a way that it now reacts strongly against human blood. A serum obtained from it, among other things, gives in a test-tube a whitish precipitate with the proteins of human blood—even if these have been merely extracted from a dried blood stain. With the proteins of chicken blood, on the other hand, it gives little or no reaction. An anti-chicken serum shows exactly the opposite behavior, reacting with chicken but not with human blood. This is the so-called precipitin reaction.

An even more dramatic method of identifying blood is by a test which succeeds best with the guinea pig. A normal guinea pig is ordinarily not harmed by the introduction into its circulation of blood from some other animal, provided that this is not done more than once. But if a preliminary sensitizing dose of a minute amount of, say, human blood is given in the proper way to such an animal, this particular kind of blood becomes a deadly poison to the sensitized animal and a subsequent dose of even a fraction of a drop may kill it within a few minutes. Other kinds of blood than that used for sensitization, however, remain relatively harmless.

When fresh blood is available for examination, specific differences may sometimes be detected by extremely simple methods. For example, the blood of the horse on standing rather quickly separates into an upper colorless and a lower red layer. The blood of the ox, which is otherwise identical in appearance, generally remains red throughout. The blood of the mouse can be distinguished

from that of a large number of other animals by the fact that, when a drop of it is added at room temperature to a 3.7 per cent. solution of a substance called erythritol, a transparent red solution is obtained in about five minutes. The other kinds of blood give turbid suspensions, which usually require hours to become clear. The blood of the chicken differs very strikingly from that of the duck and the pigeon in the slowness with which it forms a clear solution in water. Many other examples of this sort might be mentioned, though they are as yet of little practical importance.

Blood not only tells us about differences between animals but about resemblances. For example, the precipitin reaction is specific in the sense that it is most intense with the blood of some particular kind of animal. But it occurs to a lesser extent with the blood of other related animals. Thus, an anti-dog serum gives the best reaction with dog's blood, but a fairly good one with the blood of the fox, a much less marked one with the blood of the cat and so on. One of the most interesting tests of blood relationship of this sort was made some years ago by Friedenthal, who was able to demonstrate by the precipitin reaction a relationship between the blood of a living elephant and that of a Siberian mammoth that had been dead and preserved in a frozen condition for perhaps 25,000 years. In this connection it is of interest to note that the blood of the higher apes, such as the chimpanzee, for example, shows a very strong resemblance to that of man—stronger even than it does to that of the lower monkeys. In view of this blood-similarity it is not surprising that the higher apes are subject to almost exactly the same diseases as man.

Blood not only tells about differences and relationships between species, but it is beginning to do so in the case of individuals belonging to the same species. Some years ago Todd and White were

able to prepare sera by means of which the blood of individual cattle could be distinguished from that of dozens of other cattle. Todd has recently extended this work to chickens and again has found it possible by a somewhat different method to identify individual chickens by their blood. In the case of brothers and sisters the bloods are very similar, but even here by the use of the most refined methods slight differences can be detected. Results such as these lead us to ask whether it will ever be possible to identify John Smith by his blood as he now can be identified by his finger prints. There is no theoretical reason for doubting that this may some day be possible, though certain practical difficulties have so far prevented much progress in this direction with human blood.

A question that is frequently asked is whether a sample of human blood can tell us the race of the person from which it came. The answer is that in most individual cases this is not yet possible, though some information may at times be obtained. We can, for example, in many cases say with a high degree of probability that a given sample of blood could not have come from a pure-blooded American Indian. It happens that in this race three of the four well-known blood groups, for which tests are made before blood transfusions, seem either to be absent or very rare, and consequently blood of any of these three types must, as a rule, come from persons belonging to other races.

Where large numbers of individuals are involved, so that statistical methods can be employed, the case becomes more favorable. For example, suppose that in India a series of 500 samples of blood were collected from native Hindus and a similar series from Englishmen living in the same region. It would be extremely easy to decide by the proportions of the different blood groups which set represented the English and which the

Hindu blood. Verzár and Weszczeky were able to demonstrate in this way very clear racial differences between the Hungarian, German and Gypsy elements of the population of Hungary, even after several hundred years of residence in the same region.

Finally, we may consider briefly what blood tells about the relationship of human individuals. In certain cases, where the relationship is that of parent to child, blood is capable of telling a great deal. The common blood groups are inherited according to definite laws which frequently make it possible to say that a given child could not belong to certain parents. An application of this principle received a great deal of publicity a few years ago. It happened that in a hospital in Chicago two new-born infants were accidentally exchanged, and a dispute arose as to which child belonged to which parents. The case fortunately proved to be one that could be definitely settled by a study of the blood groups of the six individuals involved—I say fortunately, because a certain proportion of such cases is as yet incapable

of solution. Until a few years ago the proportion of favorable cases in an average American population, according to Wiener, was only about one in four, but the recent discovery by Landsteiner and Levine of the so-called M and N factors in human blood has increased this proportion to about two in three.

The celebrated case that Solomon was called upon to decide was a much more difficult one, because it involved only three individuals instead of six. The chance of settling a case of this sort satisfactorily by a blood examination of one child and two women would until recently have been only about one in twenty, and even at present less than one in five—so Solomon was perhaps wise in not depending upon a blood test.

It is evident from what has been said that blood does not yet tell us all that we might wish to ask of it. We must remember, however, that studies of this sort have been in progress for not more than about a third of a century. Only a very rash prophet would try to predict what blood will be able to tell a hundred or two hundred years from now.

HEART DISEASE OF MIDDLE LIFE

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IT is becoming a matter of common knowledge that of the diseases which are taking off men and women in middle life heart disease holds a foremost place. The usual lay conception of heart disease is very far removed from the actual state of affairs, and so it is proposed here to discuss the heart conditions of middle life. Most people are familiar with the so-called "leaky hearts" of children, due to rheumatism, tonsillitis and other kindred infections, and for the prevention of such conditions scores of thousands of tonsils are removed every year. With these we are not concerned to-day.

What is the usual heart disease of middle age? How is it produced, and how recognized? How prevented? You must understand that the essential part of the heart is the heart muscle, which by its contraction produces the force which causes the blood to circulate. The one thing, which is all-important, is to keep this muscle in its best possible condition, so that it may stand up under the work it has to do, twenty-four hours in every day. Now the causes of a diseased heart muscle are many. They are not spectacular, and do not operate quickly. On the contrary, they are, at first sight,

insignificant, but it must be borne in mind that they operate over long periods of time.

To begin with, a muscle should be exercised regularly. Imagine an athlete preparing to enter a contest who did not exercise regularly. A heart muscle which is not regularly exercised becomes flabby, weak, poorly nourished, and in the course of years, becomes unable to fulfil its duty. Hence the necessity of men and women taking regular exercise of a kind and degree suited to their needs. The advent of the motor car, by making physical exercise more and more difficult, is contributing its share toward bad hearts. On the other hand, a heart muscle, like any other muscle, may be overstrained. The hard-working business or professional man, who takes little or no exercise in his daily life, and then goes to the woods or mountains for two or three weeks a year, and subjects himself to inordinate fatigue and strain, is apt to do himself more harm than good. It is the steady, moderate, daily exercise that keeps a heart and indeed all the muscles in good condition. Another frequent event of middle life, with its lessened physical activity, is the tendency to take on excess weight. Every useless pound the heart has to supply with blood means that much more of a strain. Here, too, there is a reverse side of the picture, for many people, in their efforts to grow thin, get themselves into a condition of poor nutrition, which again weakens their long-suffering hearts. Anemia, due in large measure to an injudicious diet, lacking in iron, is one of our commonest conditions, and the lack of this important element in the blood is a further cause of the heart's degeneration.

High blood pressure, due to a variety of causes, is a potent cause of chronic heart failure. To be emphasized is the fact that these apparently small causes, acting over a period of years, produce dangerous and perhaps ultimately fatal

results. Now how does a heart of this kind behave? What symptoms does it produce? First, bodily fatigue. The individual finds himself unable to stand exertion as he formerly did. He lacks "pick-up," as a motorist would say. A walk of a mile or two at a fair gait becomes a thing to be dreaded, not enjoyed. How general this condition of things was abundantly shown by the medical reports of the World War, which disclosed a rather discouraging state of things in young recruits, and this has certainly not improved in the intervening years. A little later, shortness of breath appears, perhaps just on climbing stairs. This means again that the heart is not quite up to its work, and the breathlessness is a sign to stop. These two symptoms, unaccountable fatigue and shortness of breath, should make every middle-aged person pause and reflect, and then subject himself to a careful looking over.

More advanced symptoms are discomfort or tenderness in the upper abdomen, due to congestion, and it is quite common to have patients present themselves for examination for supposed stomach trouble, who have in reality, a heart that is breaking down. Still later, the ankles swell, become "puffy," as we say. There is a common idea that this is a very early symptom of heart failure, whereas, it is in reality an indication that it has already existed for a considerable period of time, and is probably progressing. You should know that also in such conditions as varicose veins, the legs may swell up without any heart condition being present, but these are evident to even a casual inspection. When, however, the legs begin to swell, and there is increased bodily fatigue and shortness of breath, it means that you should have a careful examination and appropriate advice at once. The medical profession has been endeavoring for a long time to have people go to their family physician at regular intervals for

a complete examination, just as many now go to their dentist. Certainly, as middle age approaches, this is only the part of prudence.

Every one is familiar with the pathetic picture of the far-advanced patient with heart trouble—unable to lie down to sleep, with the lower part of his body swollen with the dropsy, often gasping for breath and leading an utterly wretched existence for months before his end. Let us concentrate on this one vital point, namely, that the prevention of heart disease is vastly simpler and more important than its cure.

What can an individual of perhaps forty years of age do to prevent such a state of affairs? First of all, a fair amount of exercise for the heart, which means, of course, physical exercise. Walking is easily the best form of physical exercise in middle age, because it can be done every day in the year, and requires no special equipment and not even a companion. A still more important reason is that there is not the same tendency to overdo matters, as so often happens in athletics. We might well imitate our British cousins in this respect, for they are born walkers. Many a man would do well to forget his motor car and walk to and from his office daily.

At forty many men and still more frequently women are liable to take on excess weight. This is entirely unnecessary, since in the hands of a competent physician a normal individual can control his weight under proper medical advice. On the other hand, if already overweight, do not experiment on your own initiative with diet, but consult your physician and be sure to take his advice. Another factor of importance is to secure abundant sleep. Researches con-

ducted in the last two years have shown the great importance of sunlight to health, which means that one should not read or play bridge until the wee small hours of the morning and then get up late, for by so doing one shortens appreciably the hours of sunlight. Modern science has conclusively shown the truth of the old adage, "Early to bed and early to rise."

We hear a great deal of men breaking ing down physically from overwork, and possibly occasionally one does. On the other hand, men stand up under tremendous work for decades and are none the worse for it. One of the greatest medical men, who himself lived to a ripe old age and accomplished an enormous amount of investigative work, summed up his philosophy of life in these words, "That it is worry and not work that kills the man."

We hear much of the span of life growing longer. This is true, but it is only true because we are saving more babies and children to grow up to adult life. On the other hand, fewer men of sixty reach the age of seventy now than did many years ago, and heart disease is one of the causes for this. The difficult thing for people to realize is that the degenerative heart diseases are in a large measure a product of an unwise mode of life, along the lines I have already mentioned. If we would all take regular, moderate exercise, eat a balanced diet, adequate in all respects, secure abundant sleep, stop carrying the weight of the world on our shoulders and have our own motor inspected by a competent physician at systematic intervals, we would go a considerable way towards making the sixties extend to the Biblical three score and ten.

DAGONFLY HUNTING IN OKLAHOMA

By Dr. RALPH D. BIRD

UNIVERSITY OF OKLAHOMA, NORMAN, OKLAHOMA

IT was one of those glorious May afternoons with a brilliantly blue sky, white fleecy clouds and warm sun, not too hot, one of those days which irresistibly draws one out of doors to bask in the sun and enjoy the glory of nature, that I took my insect net and camera and went dragon hunting.

A "bug-hunter" like myself finds that the ways in which insects behave form a fascinating study. When a group is chosen whose members combine beauty of form and color, interesting life histories, comparative abundance, activity of flight and moderate difficulty of capture, this study is especially interesting. Such a group is the Odonata, composed of the large, strong-flying dragonflies and the weaker, smaller damselflies which are to be found about nearly every pond, marsh or stream.

The thrill of a successful catch, when one of the big fellows falls prey to a powerful, well-directed sweep of the net, is comparable to that experienced by sportsmen in dropping a duck or pulling out a gamey bass. Even more satisfying is the pleasure afforded by a good negative after one carefully stalks and snaps a photograph of one of the wary dragons, or when by watchful waiting in the early morning hours one gets a good series of pictures on the emergence and transformance of a brown, sluggish nymph into a splendidly winged, strong-flying creature.

The place where I chose to collect was a small marshy tributary on the west bank of the South Canadian River in central Oklahoma. Although in heavy rains it is a slow stream, it was now stagnant with a black, oozy bottom under two or three feet of muddy water. No

trees nor bushes surrounded the marsh, but a heavy growth of rushes formed a fringe about the edge and grew out a few feet into the water. Yellow masses of filamentous algae, held up by bubbles of liberated oxygen, floated in the shallower places.

As I approached I could see large dragonflies darting here and there. Some of the first to attract my attention were several males of the white-tail skimmer, *Plathemis lydia*, actively flying back and forth close to the shore. A dazzling white abdomen, covered by a thick waxy pruinescence, resembling the bloom on a ripe plum, made them conspicuous, despite their moderate size. A somber blackish female, busily occupied in laying eggs, tried to slip by and avoid the attentions of the overjealous males. She lacked pruinescence and had a black tip as well as bar to her wings. Her ovipositing was simply accomplished by dipping down and tapping the water with the tip of her abdomen to wash off the eggs as they were exuded. I caught her with the net, and by twisting her head round a turn and a half, made her pose for the camera on the back of my drawing board (Fig. 1).

Out over the open water were some large reddish dragonflies, *Tramea onusta*, with conspicuous broad bars of the same color across the base of their wings. This gave their movements the appearance of the fluttering flight of a butterfly. A few individuals of another species, *Tramea lacerata*, were similarly marked with black instead of red. A pair of *Tramea onusta* came flying past in tandem, the male holding the back of the female's head by means of the claspers at the tip of his abdomen. He

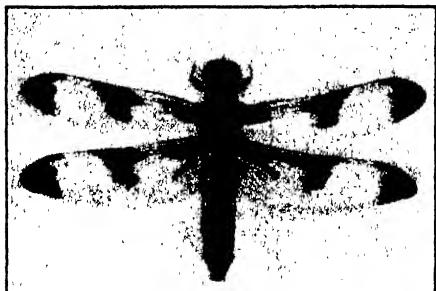


FIG. 1. A DRAGONFLY, *Plathemis lydia*.¹

assisted his less brightly colored mate while she was ovipositing. When they reached a favorable egg-laying location, they paused for a fraction of a second about a foot above the surface. Almost quicker than the eye could follow, he released his hold, she dipped down to touch the water with the tip of her abdomen, rose, was grasped by the male and away they flew to repeat the operation at another place.

Sometimes solitary individuals would fly about a foot above the water close to the fringe of rushes, hovering in the quieter spots for a second or less. So engaged, they were distinctly seen to catch small insects in flight.

While I watched the hovering *Trameas*, a big dragon, giant of them all, came darting rapidly past. His bright blue abdomen, marked with a dorsal brown stripe, green thorax and clear wings distinguished him as the male of the green darter, *Anax junius*. He did not have the fluttering flight of the *Trameas*, but flew in a more or less straight line close to the rushes or out over the open water, occasionally hovering and catching an insect in flight by swooping it up from below in the manner of a fish rising to the bait. His six spiny legs were held to form a basket to catch the luckless mosquitoes and smaller fry. Later, he was seen flying in tandem with his duller but similarly

marked mate. This species oviposited in tandem by alighting for a few seconds on dead floating rushes or cattails, while the female made a few stabs below water into the tissues of the plants with her ovipositor and inserted her eggs. These strong-flying individuals are often seen hunting over fields miles from water. They are difficult to capture with a net, but by watching them for a few minutes I could generally find that they regularly passed along a favored stretch of shore or along a narrow neck of water. By waiting there with a ready net, they could be taken with a swift sweep from behind, never from in front, for they would surely dodge. A rustle of wings in the net told of a successful sweep. It was not as easy as it looked and there was a good deal of sport connected with catching them.

On approaching the pond, my attention was at first drawn to the larger species, but at I looked more closely at the water I saw myriads of exquisitely beautiful little damselflies. The two commonest species, *Enallagma civile* and *Enallagma basidens*, were an azure blue with black markings. The former was the larger of the two, but without examining them in the hand they looked much the same and were found closely associated. Some were sitting low on rushes, all facing into the wind. Three or four might be perched one above another on an upright rush, like so many pennant flags. Others were flying out over the open pond so low that they almost touched the surface, always facing into the wind as fish would face the current in the stream, and taking quick flights down the wind only to regain their position. This habit was indulged in more by *Enallagma civile* than by the smaller and weaker *Enallagma basidens*. These activities were followed mostly by the unmated males, which always appeared much more abundant than the females. Practically all females ob-

¹ The photographs in this article were taken by the author in May, 1932.

served were in tandem with a male and spent most of their time egg-laying.

The floating masses of filamentous algae appeared to be favored for ovipositing. There were a dozen or more pairs in a patch not over a yard square (Fig. 2). They would alight on the algae, the female first holding the abdomen out horizontally or slightly elevated, but in a few seconds she would start to oviposit by bending her abdomen down into the algae and immersing it for about half its length, probing about, inserting her eggs with the ovipositor. The male meanwhile either tried to balance himself at an angle of about forty-five degrees or let himself down and hung on the algae with his body parallel to the water surface. He would continually flutter his wings and either fold his legs close to the body or let one or two dangle. The pair would remain in one place for a minute or two at a time.

Associating with their blue and black cousins were a few orange and black *Enallagma signatum*, which blended so closely with the algal color that they were difficult to distinguish. There were both solitary males and tandem pairs. Occasionally they would take short

flights out over the open water, flying very close to the surface. The males were pugnacious and chased each other and the more abundant *Enallagmas* when they ventured too close.

The main activity of the tandem pairs was ovipositing. One pair which I watched and timed was particularly interesting. They lit on top of a pond weed, and the female began at once probing about below the surface with her ovipositor while the male balanced himself as best he could. He kept his legs and wings folded and his body rigid. Finally he let himself down and hung on to a piece of floating algae. Meanwhile, his mate backed farther and farther down the stem until only her thorax was above water. She was apparently held up by the surface tension which bent the water film down into a distinct trough about her. At last it broke and she was completely submerged. Undaunted, she continued backing down until all but the thorax of the male, who still clung to his mate, was under water. After about ten minutes of egg-laying she came to the surface for a few minutes, never ceasing to probe about, then backed down again. At this time the



FIG. 2. THREE PAIRS OF OVIPOSITING DAMSELFLIES, *ENALLAGMA CIVILE*. THE MALE HOLDS THE FEMALE AT THE BACK OF HER NECK BY MEANS OF THE CLASPERS AT THE TIP OF HIS ABDOMEN. WHILE THE FEMALE IMMERSES HER OVIPOSITOR AND PROBES ABOUT LAYING EGGS, THE MALE SUPPORTS HIMSELF ON THE ALGAE OR BALANCES HIMSELF WITH FLUTTERING WINGS IN MID-AIR.



FIG. 3. POND ON THE BANKS OF THE SOUTH CANADIAN RIVER NEAR NORMAN,
OKLAHOMA,

WHERE DRAGONFLIES AND DAMSELFLIES ARE COMMON. THE RUSHES IN THE FOREGROUND ARE
FILLED WITH EGGS LAID BY *Lestes alacer*.

male, being annoyed by an *Enallagma civile* trying to sit on his head, deserting his partner, let go and flew away. She stayed down for about ten minutes more before coming up so that her thorax was above water. A male *Enallagma basidens* at once lit on her and tried unsuccessfully to take hold of the back of her neck. Thus bothered, she again went down, this time for fully twenty minutes, descending about two inches below the surface. She was visible all the time and could be seen thrusting about in the pond weed inserting eggs into the leaves. When she finally came up, her body moved by jerks, because, being lighter than water, when she loosed her hold, she would float up. A film of air could be seen about her thorax. Her body and wings did not appear to be wet after the submergence, and she flew off without difficulty when she reached the surface. She lit

on a near-by rush where she carefully attended to her toilet of wiping off and polishing her body.

Flitting about among the rushes, scarcely daring to trust their feeble wings to the wind away from their shelters, were the exquisite little damselflies, *Ischnura verticalis*. Their thorax was green and the tip of the abdomen blue, the rest black. The dark color was hardly visible against the background of the rushes, so that all one saw was two widely separated green and blue dots slipping along.

After studying, collecting and photographing here, I moved on to a pond at the head of the stagnant stream (Fig. 3). It had a hard bottom and a scattered growth of rushes about the edges. All the species seen at the other location were here, and in addition a number of larger, somber-colored damselflies, *Lestes alacer* and *Lestes forcipatus*. The for-



FIG. 4. A TANDEM PAIR OF *LESTES ALACER*

OVIPOSITING ON A RUSH ON THE SHORE ON THE POND IN FIG. 3. THE ROW OF EGGS MAY BE SEEN JUST BELOW THE FEMALE, SOMEWHAT OUT OF FOCUS BUT STILL VISIBLE.

mer were more abundant, but both had the same habit of egg-laying in the rushes well above water line. The many ovipositing pairs had filled practically every rush with eggs in irregular vertical rows two or three inches long. Females seemed to prefer to insert the eggs along the angle rather than along the flat side, although some were found in both places. Their presence was indicated by oval, whitish dots of dead tissue. I watched and photographed one pair as they worked (Fig. 4). The male would bend his abdomen into a semi-circle and keep his tightly folded wings elevated. The female half spread her wings and bent her abdomen in almost a complete circle so that the ovipositor was almost touching her thorax. She would lay a number of eggs without changing her position. After ovipositing on one side for about five minutes, she shifted to the opposite side of the rush, continued for another five minutes and then flew away.

Clinging to a number of rushes were the brown cast-off skins or exuviae left when the immature dragonflies and dam-

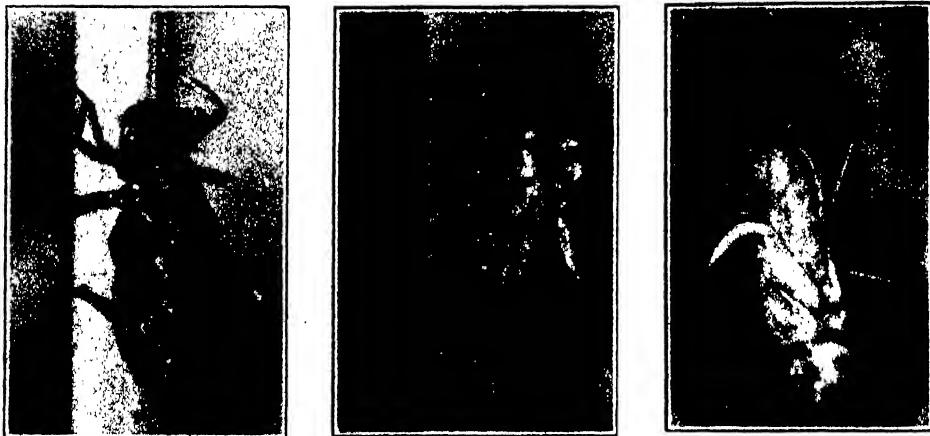
selflies moulted for the last time to become adult. Dragonflies spend their early stages under water as inconspicuous nymphs, obtaining oxygen from the water by means of gills, and living on small aquatic animals. Mosquito larvae are their favorite food, although some of the large nymphs will attack tadpoles and even small fish. After a life of a year or more, during which they moult a number of times, they climb out of the water and shed their skin the last time to become adult. This emergence and transformation takes place early in the morning, so a few days later I went out and was lucky enough to observe the change in both *Enallagma civile* and in a dragonfly, *Gomphus militaris*.

It is during the few hours of emergence and the time shortly afterward



FIG. 5. EMERGENCE OF *ENALLAGMA CIVILE*

THE EXUVIAE IS IN THE LOWER LEFT AND THE NEWLY EMERGED ADULT AT RIGHT. THE EXUVIAE OF ANOTHER INDIVIDUAL IS AT THE UPPER LEFT.

FIG. 6. EMERGENCE OF *SYMPETRUM CORRUPTUM*

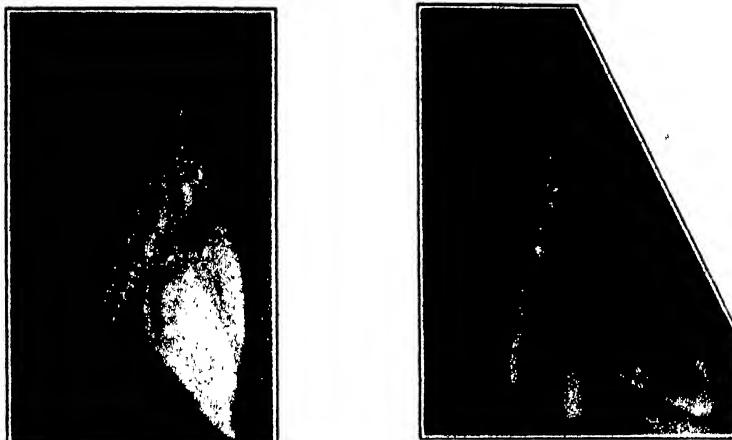
LEFT. THE NYMPH, STILL WET AND SHINY, FIRMLY GRASPS THE RUSH. CENTER. THE SKIN SPLITS AT THE BACK OF THE THORAX. RIGHT. THE PARTIALLY EMERGED ADULT, STILL TOO WEAK TO PULL ITSELF TO AN ERECT POSITION, HANGS HEAD DOWNWARD BY THE TIP OF THE ABDOMEN STILL ENCLOSED IN THE NYMPHAL SKIN.

that these insects are in their greatest danger from enemies. At this period their bodies are soft and the unexpanded wings are incapable of flight. The helpless dragonflies are frequently overpowered by swarms of ants or waiting spiders. Birds gobble them up in great numbers as the weak adults flutter feebly from their exuviae to the near-by vegetation.

On the morning of May 10, great numbers of *Enallagma civile* were emerging between seven and eight o'clock. At this time of day the water was much warmer than the air. The nymphs would crawl up the rushes growing in shallow water close to shore. The one which I watched particularly in all stages of its emergence, from the time it left the water at 6:52 a. m. until it flew at 8:20, behaved as follows:

The larva crawled up the rush about an inch above the water and took a firm hold by embracing it as closely as possible with its legs. It was at first wet and shiny but soon dried. After seventeen minutes the skin cracked between its shoulders and at the back of the head. The thorax was the first to emerge; then

the head and legs. It stood out from the stem supported only by the end of the abdomen, which was still in the exuviae. After a pause of nine minutes, during which time it gained strength, it reached down, grasped the exuviae with its legs and pulled out its abdomen. Now free from its moulted skin, but still soft and colorless, it moved to the sunny side of the rush and could soon see well enough to react to my movements a foot or more away. The abdomen, at first longer than the wings, was short and compact. The wings were literally blown out, as one would blow out a toy balloon, with the tips being the last to expand. Half an hour after the time when the skin began to crack, the wings were completely expanded and had become three sixteenths of an inch longer than the abdomen. The abdomen then began to grow and telescope out with a sort of pumping action. In about an hour it was a quarter of an inch longer than the wings (Fig. 5). Five or six drops of a clear liquid were expelled. After resting and gaining strength, the insect cleaned its face by rubbing with its front legs. Ninety

FIG. 7. EMERGENCE OF *SYMPETRUM CORRUPTUM*

LEFT. THE ADULT HAS PULLED ITSELF FREE FROM THE EXUVIAE TO WHICH IT STILL CLINGS. THE WINGS BEGIN TO EXPAND BUT ARE MILKY AND WRINKLED AT THE TIPS. RIGHT. THE ADULT HAS MOVED PARTLY OUT OF FOCUS. WINGS AND ABDOMEN ARE BEING EXPANDED. THE WINGS AT THIS STAGE ARE LONGER THAN THE ABDOMEN.

minutes after the skin cracked it flew to the vegetation back from the pond. At this stage it was termed a teneral. It would not gain full coloration for several days.

I had hardly finished making observations on the *Enallagma* when I saw the nymph of a dragonfly, *Gomphus militaris*, crawling in very shallow water. It crawled out of the water, but, apparently finding conditions unsatisfactory, would return. It spent about a quarter of an hour looking for a place to transform and finally came to rest with only its back above water. Here it went through much the same changes as did *Enallagma civile*, except that, being flat on the ground, it first stood erect on its abdomen.

On this particular morning, I was too late to observe the emergence of some of the other species, so a week later I returned to the pond, this time at 5:50 A. M. The sun was just up and a heavy mist was arising from the water. Even at this early hour I found I was too late for the emergence of *Anax junius*, for I saw three completely developed tenerals ready to fly from their exuviae. Another

specimen, not so fortunate, had been overpowered and killed by a swarm of small yellow ants.

My early trip was not in vain, for at 6:40 I found a wet and shiny nymph of *Sympetrum corruptum*, which had just crawled up a rush about six inches above the water. I had plenty of time to set up the camera and make myself comfortable for taking pictures and notes. This species took two hours for its complete emergence. It differed from the others I had watched in that when it had pulled its head and thorax from the larval skin, it was too weak to pull itself up and had to hang head downward by the tip of its abdomen for at least fifteen minutes. The accompanying illustrations (Figs. 6 and 7), show how a squat, compact, aquatic creature changes into a graceful being ready to soar away and conquer a new element, the air.

Such are the experiences of a modern dragon hunter—perhaps not as exciting as those of the fabled knights of old, but thrilling to those in search of the scientific adventures which may be found close to home.



PROFESSOR HUGO DE VRIES

THE PROGRESS OF SCIENCE

THE WORK OF PROFESSOR HUGO DE VRIES

ON February 16 last, Hugo de Vries, the Dutch botanist, celebrated his eighty-fifth birthday. To few living scientists has it been the lot to have influenced so profoundly the theory and experimental practise in their chosen fields. He was able to bring to bear upon his investigations a combination of mental qualities which are rarely found developed to the same degree in a single individual. He has been a keen observer, a patient accumulator of data, an energetic experimenter, skilful in interpretation of evidence and yet able to relate his findings to broader problems. He has been a man of theory and vision as well as a gatherer of details in laboratory and garden.

De Vries was born at Haarlem, Holland, in 1848. He received his doctorate from the University of Leiden in 1870 with the thesis entitled "The Influence of Heat on Life Phenomena in Plants." Later he studied in the German universities of Heidelberg and Wurzburg and at the latter university and at Halle carried on investigations for the German Department of Agriculture. In 1877 he came to the University of Amsterdam as lecturer in plant physiology, where he eventually became professor of plant physiology. He retired in 1918 and since then has lived in Lunteren, Holland, where he has a small greenhouse and an experimental garden in which he still continues his studies on the evening primroses.

De Vries has always been classified as a botanist, but his early work on the causes of turgor in plants has had important influence on the development of theories in chemistry. He extended the plasmolytic method as a means of determining the osmotic pressures exerted by the sap within living cells. He thus determined the relative influence of molecular solutions of different salts and or-

ganic compounds upon osmotic pressure and expressed these differences in terms of his isotonic coefficients. Upon these studies, Van't Hoff and Arrhenius based their laws of dissociation in dilute solutions which form one of the fundamental concepts of modern physical chemistry.

De Vries is most widely known for his influence on biological thought. In 1889 he presented his theory of intracellular pangenesis in which, on the basis of extensive observations, he argued for the existence of hereditary particles in all cells corresponding to the different characters in the organism. He thus early visioned our modern concept of the gene. Strasburger, in his foreword to Gager's translation of "Intracellular Pangenesis," writes as follows: "By creative imagination Hugo de Vries predicted much in his book that gained a material basis only through the histological research of the following decades . . . he predicted phenomena which were to furnish the basis for our conceptions of fertilization and heredity but which have become actually known to us only through later works on the most intimate processes of nuclear division." His powers of prophetic imagination are also shown in an address entitled "The Aim of Experimental Evolution," which was delivered at the opening of the Station for Experimental Evolution in 1904.¹ He urged that attempts be made to alter the hereditary particles in the germ cells by different kinds of external stimuli. He pointed out that x-rays and radium have proved themselves capable of provoking important changes in living organisms. "If the same holds good for our dormant representatives in the egg," he said, "we may hope some day to apply

¹ This address is published in the third Yearbook of the Carnegie Institution of Washington, but does not appear in the reprint series of de Vries' papers, "Opera e Periodicis Collata."

the physiological activity of the rays of Röntgen and Curie to experimental morphology." It was nearly a quarter of a century before this hope was realized.

De Vries was one of the three wise men of the eastern hemisphere who in 1900 independently rediscovered Mendel's law of inheritance and thus dated the beginning of the modern science of genetics.

His greatest influence on biology has come from his mutation theory, presented in two volumes in 1901 and 1903. This was supported by a wealth of observation and experiments. His idea that normal evolution is by sudden jumps rather than by gradual change and that evolution can be observed experimentally was a tremendous stimulus to scientific experiments in plant and animal breeding. Darwin was a good botanical experimenter, but his followers seem to have favored observation and speculation. De Vries' greatest service to biology has been in making experimentation the basis of evolutionary theories.

The Evening Primrose (*Oenothera Lamarkiana*), flowers of which he is holding in his hands in the photograph, has been the object of his investigation during all his later years. In 1886 he found plants of this species growing in a field near Hilversum, Holland, and

among them a number of variants. He believed he had found a species which was in a stage of rapid evolution and mutating off "elementary species." For about a decade he carried on investigations on these *Oenotheras* in secret before publishing his results. They formed the main support for his mutation theory. Many other investigators have since taken up the study of *Oenotheras*, and the literature on the genetics of the genus has reached an enormous volume. The mutations which the Evening Primroses produce in such relatively large numbers are not now thought to be elementary species in quite the sense that de Vries first believed, but this fact need not detract from the value of the mutation theory to which they gave rise. The *Oenothera* investigations have given us information on a type of inheritance and genetic change that is more common than was once supposed. They are still giving us information about the origin of species.

We wish many more years to the genial grand old man of Lunteren, but the name of Hugo de Vries will always live as that of one of the master minds of science.

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CARNEGIE INSTITUTION
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THE EARTH SCIENCES AT A CENTURY OF PROGRESS

EXHIBITS descriptive of a century's advance in the earth sciences will form an integral part of the displays in the Basic Sciences Division of Chicago's 1933 "Century of Progress" Exposition, the general features of which were described by Professor Henry Crew in the September issue of the SCIENTIFIC MONTHLY under the title "Exposition of Science."

The earth sciences, comprising such fields as geography, cartography, physiography, meteorology, mineralogy, physical, historical and economic geology,

have played an important rôle in the development of our modern industrialism. Indeed, with physics and chemistry, they have largely sponsored the "technical ascent of man." To cite only a few examples, meteorology has made possible weather forecasting and man's commercial conquest of the air; geography and cartography are responsible for his knowledge of the face of the globe and his varied, planned adaptations to its physical features and climatic zones; and to geology goes much of the credit for making available raw



STREAM TABLE EROSIONAL AREAS WITH SPRINKLER REMOVED

THE STREAM IS FED BY THE FLOW FROM BURIED RUBBER TUBES. THE REGION IN THE MID-AREA OF THE PHOTOGRAPH HAS BEEN SLIGHTLY IMPOUNDED AND THE GRADIENT INCREASED DOWNSTREAM, WHERE, AS A CONSEQUENCE, RAPIDS HAVE FORMED.

materials upon which our present economic structure is based. One hundred years ago the United States produced no petroleum, practically no lead, zinc or copper, and only insignificant quantities of iron and coal. Indeed so little gold was mined at that time that our total per capita amount was only about three cents. To-day, owing to great advances in the science of geology and the profession of geological engineering, practically all the mineral resources of the

country have become known, and the normal production of most of our raw materials goes on at a rate which is almost incomprehensible.

The direct social consequences of the geologist's development of the petroleum and other mineral resources of the world are far-reaching and commonplace. But, equally important and less well known is the fact that geology develops an appreciation of the enormous duration of time involved in the gradual evolution



THE HALL OF SCIENCE OF A CENTURY OF PROGRESS
THE EARTH SCIENCES EXHIBITS ARE HOUSED NEAR THE MAIN ENTRANCE IN THE RIGHT WING OF THE BUILDING.



DIORAMA OF A BATTLE BETWEEN THE THREE-HORNED TRICERATOPS AND TYRANNOSAURUS

CRETACEOUS DINOSAURS WHICH LIVED ABOUT ONE HUNDRED MILLION YEARS AGO IN THE AREA WHICH NOW MAKES UP OUR WESTERN PLAINS.

of the earth and its inhabitants. It demonstrates the continuity of the past and the present, and furnishes the background for an understanding of man's origin and his present place in nature. Geology also deepens man's esthetic appreciation of scenic wonders through imparting a knowledge of the processes through which the great physical features of the earth have originated.

Much of this information is, of course, well known to the technically trained citizen, but most of the facts have never been fully realized by the "man in the street."

The Section of the Earth Sciences at A Century of Progress will appropriately feature, therefore, a "giant clock of the ages," which will be shown ticking off the eons involved in earth history. All the two billion years or more of this epic account will be seen on the clock dial as occurring in one conventional hour, although the "minute hand" will actually complete its "hour" circuit in about four minutes. As the rapidly moving "minute hand" reaches successive points of great geological interest, an appropriate sequence of geological scenes will appear on the screen in the center of the dial, and each scene will be described by means of a synchronized phonographic record.

But although the "clock of ages" will strike the keynote of the earth sciences' story at A Century of Progress, there will be a wealth of dynamic individual exhibits calculated to tell completely and intimately the complicated story of the origin and growth of our own planet. Space does not suffice for a detailed account of these exhibits, but the visitor will see, for instance, animated displays showing the processes of erosion and deposition which have so largely shaped the face of the earth. These processes acting very slowly in nature will be shown in greatly accelerated fashion in a mechanical device known as a stream table. Dioramas, or three-dimensional pictures, showing some of the animals of the past, will form a part of the section on paleontology, in which the main theme will be the life of former geological periods. The visitor will also find operating models demonstrating the formation of mountain ranges, the growth and activities of volcanoes and the eruption of geysers; and he will be initiated into the mysteries of earthquakes and the manner in which man has forced them to write their own records. A group of important displays of similar type, representing earth features as exemplified in our national parks, such as the Yellowstone geysers, Bryce, Yosemite

and Grand canyons, Carlsbad caverns and Kilauea crater, are being built by the National Park Service.

The origin, accumulation and migration of oil and gas will be completely demonstrated in a great sequence of operating exhibits sponsored by the American Petroleum Industries. These exhibits, many of which are already constructed, cover every phase of oil and gas production. Other displays will explain man's modern, almost magical, methods of locating the deeply buried metallic and non-metallic products, and the methods used by him in winning these raw products from the earth.

In short, while the Century of Progress will dramatize the last hundred years of man's scientific advance, the displays in the earth sciences will attempt to vitalize for the public the many millions of years involved in the earth's history. Furthermore, they will point out, in simple fashion, just how and why the earth is continually changing its facial expression, they will call attention to the many strange animals and plants which it has nourished, and they will explain the origin and distribution of its great mineral resources.

CAREY CRONEIS
In Charge of Geology Section

DR. GEORGE O. CURME, JR., RECIPIENT OF THE CHANDLER MEDAL

THE Chandler Medal was presented to Dr. George O. Curme, Jr., on March 17 at Columbia University, for his notable contributions to the advancement of the applications of chemistry to industry. Dr. Curme carried out his graduate work at Northwestern University, the University of Chicago and in Berlin. He has been associated with the Union Carbide and Carbon Corporation since 1914 and is now vice-president and director of research of the Carbide and Carbon Chemicals Corporation.

Dr. Arthur W. Hixson, professor of chemical engineering at Columbia University, and chairman of the award committee, in commenting on Dr. Curme's work said:

"Although the achievements of Dr. Curme are only now beginning to be recognized, it is of significant importance that his ideas and his thoughts as expressed to his intimate friends have changed but little in the fifteen years that have elapsed since he began this work. He saw clearly in 1915 and 1916, before anybody else appreciated the possibilities, just exactly what is happening to-day in the field of aliphatic chemistry and he predicted in those days the industrial use of these aliphatic com-

pounds in quantities reaching into the millions of pounds per month, although at the time only test-tube quantities were available.

"The achievements of Dr. Curme are many. His original work involved the production of acetylene, the thermo-decomposition of mineral oil induced by sticking an electric arc beneath the surface of the oil. This was done in 1915-16.

"Subsequently he has worked out practical methods for the production of ethylene glycol, ethylene dichloride, ethylene chlorhydrin, ethylene oxide, diethyl sulfate, dichlor ethyl ether and many other compounds. Most of this work has been patented.

"Dr. Curme's greatest achievement has not been solely the working out of laboratory methods for making the compounds mentioned above, but in translating these laboratory applications to large-scale manufacturing processes. As is well known to-day, the production of ethylene glycol, ethylene dichloride, ethylene chlorhydrin and some of the other compounds mentioned runs into many millions of pounds annually.

"More recently his early work in connection with the production of synthetic isopropyl alcohol and acetone has been



DR. GEORGE O. CURME, JR.

commercialized and these products are now available on a large scale. He is considered one of the greatest living exponents of aliphatic chemistry.

"The achievement that has attracted the most public interest has been the manufacture of synthetic ethyl alcohol, which was put into production in a large way during April, 1930, but the

preliminary work for it had been done and the process well outlined over ten years ago."

The Chandler Medal and Lectureship were instituted in 1910 by friends of the late Professor Charles Frederick Chandler, of Columbia University, pioneer in industrial chemistry and a founder of the American Chemical Society.

THE METRIC SYSTEM IN TRACK AND FIELD EVENTS

ON November 22, 1932, the Amateur Athletic Union "went metric." It may, perhaps, be interesting to inquire what effect this action by the Union will be likely to have upon athletic events, and records in those countries in which, up

to this time, distances for such events have very generally been expressed in yards, feet and inches.

First of all, it should be pointed out that from the standpoint of measurement athletic events fall into two general

classes—first, field events in which measurements of distance only are involved; and second, track events, in which measurements of distance and time are involved. The high-jump, broad-jump, pole vault, shot-put, discus-throw, hammer-throw, etc., fall within the first class, while the dashes, hurdles and other running events, of course, fall within the second class.

It is evident that field events will not be greatly affected by the adoption of the metric system of measurement. In all such events the height or distance attained by the contestant, whether measured in feet, inches and fractions of an inch, or in meters and fractions of a meter, can readily be converted from one system of measurement to the other. Records of past performances can also be readily converted. All that is needed is a convenient and accurate table of equivalents.

When we consider track events, however, we find a quite different situation. In these events standard distances are set up, in terms of a unit of length, either the yard or the meter, and the contest in each event consists in running this standard distance in a minimum time.

The standard distance chosen for each event is some integral number of yards or of meters, depending upon the system of measurement employed. For example, 100 yds., 220 yds., 440 yds., etc., or 100 meters, 110 meters, 200 meters, 400 meters, etc.

Obviously, the distances set up for a series of events under one system of measurement will not be appropriate for a series of similar events under the other system of measurement. Two entirely different series of distances will therefore be necessary, and it will not be possible to set up a table of equivalents for track events held under the two systems of measurement; and records made under the two systems will not be comparable. They represent, in fact, an entirely different series of events.

It may reasonably be assumed that

other athletic organizations will follow the lead of the Amateur Athletic Union in adopting metric distances, and, with the above situation in mind, a question naturally arises as to what is likely to happen with reference to track records, for distances measured in yards, that are now on the books, if and when these events are no longer run.

Obviously, if the events are no longer run the present records can not be broken and will stand indefinitely. Such a record will, no doubt, when no longer subject to assault, lose some of its significance and relative value. To that extent the change can hardly fail to involve some disappointment to present record holders for distance events measured in yards. There is, however, a compensating advantage in that these records can not be broken and are therefore safe for all time, no matter how future athletes may "burn up the cinders."

In order that the layman, who is not entirely familiar with the metric system, may get the habit of thinking in terms of meters it may be well to give a few equivalents that will help to correlate some of the more important metric distances with the yard distances with which he is familiar:

	Yards	Meters	Meters	Yards
	50 =	45.72	50 =	54.68
	100 =	91.44	100 =	109.36
	120 =	109.73	110 =	120.30
	220 =	201.17	200 =	218.72
	440 =	402.34	300 =	328.08
	880 =	804.67	400 =	437.44
(1 mile)	1760 =	1609.35	500 =	546.81
(2 miles)	3520 =	3218.69	800 =	874.89
			1000 =	1093.61
			1500 =	1640.42
			2000 =	2187.22
			3000 =	3280.83

Note: The above equivalents are approximate, but are correct to the number of decimal places given.

H. W. BEARCE,
*Co-Chief of the Division
of Weights and Measures*
NATIONAL BUREAU OF STANDARDS

THE SCIENTIFIC MONTHLY

MAY, 1933

THE FUNGI OF BARRO COLORADO

By Dr. WILLIAM H. WESTON, JR.

LABORATORIES OF CRYPTOGAMIC BOTANY, HARVARD UNIVERSITY

IN these days, when the demand for mouse-traps has appreciably declined and the trend of the public's purchasing is influenced chiefly by colossal advertising campaigns, there may be some doubt about the world making a path to that door where better mouse-traps are being manufactured. There is, however, no doubt at all that to the door of a biological station which offers unparalleled advantages in the rich field of tropical research, appreciative investigators will make their way in enthusiastic and ever-increasing numbers. Such a station is Barro Colorado, with comfortable and well-equipped laboratories most advantageously located at the edge of some six or so square miles of untouched tropical jungle, covering the irregular, wheel-shaped contour of Barro Colorado Island, as it lies in fortunate isolation surrounded by Gatun Lake, with the Bohio and Buena Vista Reaches of the Panama Canal and a stately traffic from the seven seas bounding it on two sides. And the path which has been worn to the door of the station is an easy five to seven days' travel from New York to Christobal by comfortable steamers, an hour of enjoyable train ride on the historic Panama Railroad to the little lake-side village of Frijoles, and an interesting and all too brief three miles by boat across Gatun Lake to the laboratory wharf. Is it not to be expected that

biologists, naturalists and interested travelers should have come in growing numbers to this station, since through the energy and perseverance of a few far-sighted biologists, such as Thomas Barbour and James Zetek, it made its modest beginning seven years ago? Is it not wholly to be expected also that from those who have worked amid the unforgettable atmosphere and the unusual facilities and advantages of this station there should come numerous and diverse writings telling the world all about it? It is to be expected—even of scientific men.

As early as 1927, in his interesting Smithsonian Report on the Station, Professor Gross, of Bowdoin, listed a growing literature of over fifty titles relating to the island, and to this nearly double the number have since been added, until it can be said that they represent a varied list, from abstruse scientific papers read only by specialists, to articles with the deft popular touch and the excellent photographs that have universal appeal. As a result the island and the more interesting aspects of its plant and animal life are known not only to scientific men but to laymen as well, and if you are not as yet Barro Colorado conscious you have but to consult Dr. Chapman's delightful and informative "Tropical Air Castle" to know it at its best.



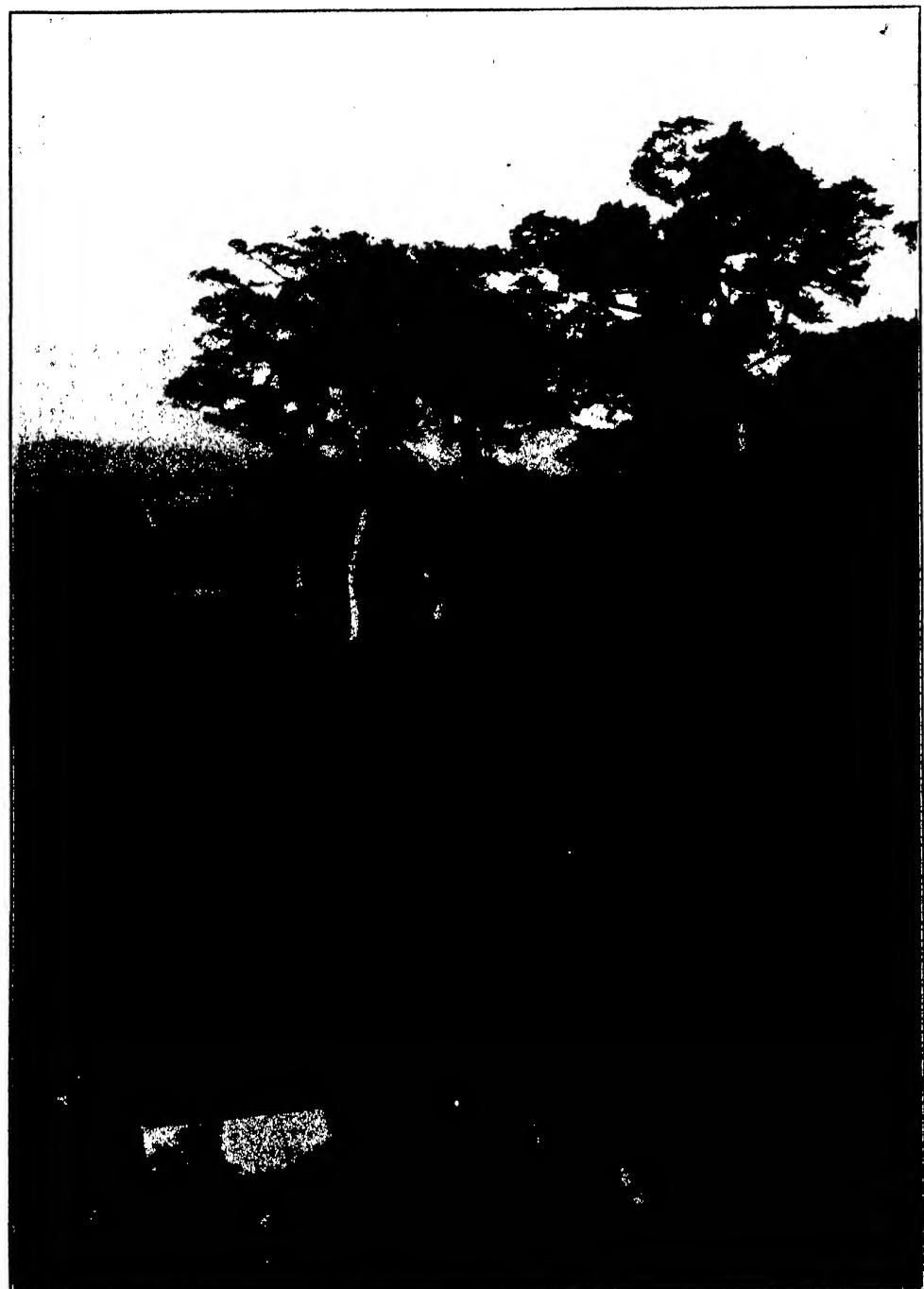
THE LABORATORY IN ITS CLEARING
AGAINST THE RISING WALL OF JUNGLE, DR. CHAPMAN'S "CASA MIA" AT THE LEFT, WITH
A STOREHOUSE AND THE BANANA PLANTATION BELOW.

Yet in all this galaxy of literature little has been said of the fungi of Barro Colorado, and this is wholly natural, for in general appeal not even the deadly manchineel and the legendary upas tree, nor aristocratic and alluringly romantic orchids can hope to compete with sonorous howler monkeys or aloof nocturnal cats, with gaudy and clamorous toucans, superbly soaring vultures or colorful and cacophonous parrots. Much less can the humble fungi claim popular attention; they utter no haunting cries from the depths of the forest, nor do they flaunt flaming wings across your line of vision. Yet they are not without interest. Their remarkable diversity of form, structure and method of growth, their distribution in relation to different environments and to diverse substrata, their rapid and surprisingly efficient methods of development, their parasitism or saprophytism and their relation to plants, to animals, and even to man, commend them for a certain share of attention. Moreover, it should be remembered that without their activities this great cycle of jungle growth could not go on, since the whole vast machinery of plant life and of the animal life dependent upon it is prevented from being clogged with accumulated material by the activities of fungi in breaking down complex, elaborated substances into raw materials once more.

To one who is fortunate enough to live on the island, as I did, from October to May, it is apparent that there is a seasonal abundance and diversity of fungi directly related to moisture. During the rainy season from May through November when the great proportion of the more than 130 inches of rainfall occurs, winds are rare, and in the depths of the forest the air hangs breathless, saturated and still, so that fungi may grow in the dense tangle of jungle as undisturbed as they would in a green-

house or a laboratory culture chamber, providing they are located where the direct downpour or the runlets and splashings of water can not strike them. It is surprising to one from a temperate climate to note, under the favorable conditions of this season, the abundant development of fungi on dead branches caught in the entangling creepers far overhead or on graceful palm leaves which, as they age, droop down and hang still fastened to the tree, or on whole tops of trees which, weakened by the tunnellings of termites and dragged down by their heavy burden of vines, have given way in some occasional storm and remain suspended above the ground, swung by the very strangling growths that have helped to cause their death. On such material the diversity of forms ranges from large, obvious, fleshy or woody fungi to the most delicate and evanescent moulds and *Myxomycetes*, which successfully form their exquisitely fragile sporophores in situations where the slightest jarring of the substratum shakes off a powdery shower of spores.

Out of the abundance and diversity of fungi developing during the rainy season certain groups and certain genera are so obvious as to strike the attention of even the casual passer-by along the trails, while others are to be discovered only after an intensive search guided by the experience or intuition of the trained collector. In general, it is in the order of their conspicuousness that fungi are collected in a new locality, and in the forest of Barro Colorado, just as in our own woodlands, it is chiefly the large, fleshy or woody Basidiomycetes and to a lesser degree some of the cup fungi and *Pyrenomyces* that catch the eye. Among the Basidiomycetes the most obvious were chiefly the wood-destroying forms, both saprophytes and wound parasites; but the forms common with us, such as *Fomes annosus*, *Poly-*



VIEW FROM THE LABORATORY

OVER THE SHELTERED INLET PAST THE WALL OF THE JUNGLE ACROSS THE BUENA VISTA BEACH
OF THE CANAL.

porus betulinus, *Polystictus versicolor*, and others, were lacking here, while, in contrast, representatives of certain related genera, rare or wholly lacking in our own country, were of common occurrence. *Hexagonias* (chiefly *H. tenuis* and *H. variegata*) were found growing on wood in abundance, their hexagonal pores in delicacy and regularity far surpassing biology's classic examples of six-sided construction, the cells of honeycomb; while delicate *Laschias* (*L. auriscalpium* and *L. Pezizoides*), the smallest of the Polypores, usually rewarded an intensive search through débris of palm leaves. The usually ubiquitous *Schizophyllum* was rare here, and instead it was species of *Auricularia* that occurred everywhere, chiefly *Auricularia polytricha*, whose tough, rubbery little portes cochères, with their inconspicuous, brown, fuzzy tops, protruded from nearly every dead branch or twig not only in the moist shade near the ground but even high up near the forest roof, where I noticed it when I had climbed over 100 feet up in the great sand box tree renowned by Allee.

It was noticeable that the conspicuous fungi were chiefly those growing on wood, for in this tropical forest there is no autumn fall of leaves to carpet the ground and fill hollows and depressions with deep, matted, moisture-holding drifts ideal for the development of a mycelial network of fungous threads in the following summer. On the contrary, the highly individual deciduous trees of the jungle do not shed their leaves in unison but scatteringly, some at the start of the dry season, some later, some just before the rains begin again, and the scant deposits of leaves thus formed do not persist, so that the forest floor is typically rather bare. Perhaps for this reason the leaf-mould inhabiting mushrooms so common with

us were few and infrequent and the picturesque motley of *Amanitas*, *Russulas*, *Lepiotas*, and the rest which enliven our New England woodlands was lacking on Barro Colorado, nor would a day's search be rewarded with a single *Boletus*, of which several species could be gathered in a square rod at home. Occasionally, groups of a most graceful agaric occurred on débris under the big trees, delicate specimens with black, slim stalks, hardly larger than coarse horse-hair, yet as much as eight inches tall, supporting pallid dome-shaped caps less than an inch in diameter. Occasionally, also, groups of white infundibuliform sporophores of *Hypolyssus Montagnei* were seen, and associated with them a densely woven, felt-like, pallid mycelium which, starting from trash on the ground, grew upward on fallen branches or twigs or even on the stems of living shrubs and vines enveloping them in a conspicuous weft that faithfully followed every contour of their surface and even sent out delicate lace-like outgrowths of its own to add decorative embroidery to the whole.

Since it was chiefly on wood that the fleshy Basidiomycetes occurred, as might be expected, they were not limited to the woody trash of the forest, but occurred on lumber and structural timber as well. Bridges, railings and stairways along difficult trails and posts and sheds near the laboratory showed the destructive ravages of such fungi, which worked in effective cooperation with the termites, while near-by in the "experimental graveyard" in which sections of telegraph poles and other timbers, both untreated and treated with various preservatives, were kept to test their resistance to these destructive agents, wood-destroying fungi were found here and there, one small white agaric with a conspicuous bisoid base being especially noticeable. Even boats and skiffs of



THE SCREENED UPPER PORCH,

A COMFORTABLE LABORATORY, WHERE DR. FRANK CHAPMAN AND DALLAS LORE SHARPE DISCUSSED BIRDS.

selected hardwoods were not exempt, and it was through the ravages of an insidious *Poria* that the tough "roble" wood of "Tom," our faithful cayuea hewn from a single great log, was so weakened that in a rough sea one of the submerged stumps of the Drowned Forest could give it the gaping wound that caused its untimely end and forced "the botanist in his foolish forties" to cut his way home through a trailless part of the jungle, as has been so graphically described by Dallas Lore Sharpe.

Among the Basidiomycetes, the Gasteromycetes or puff balls, earth stars and allied forms apparently are not a conspicuous feature on the island. The crowds of puff balls commonly occurring in our own woods, on rotten logs or on the ground, were never seen there; instead, and only rarely, were found on rotten stumps the small, inconspicuous, buff-colored forms, apparently identical

with Montaigne's *Gaster mirabilis*, which did not develop any pore, but finally, by an irregular breaking of the fragile wall, set free the stale-mustard colored spore mass within.

The Phallales, which, as their old and vulgar name of "stinkhorns" implies, are one group of Basidiomycetes that announce their presence to one's sense of smell as well as of sight, were represented on Barro Colorado by occasional examples of *Clathrus* and chiefly by a beautiful *Dictyophora* which was found here and there along the trails, its white, columnar, porous stalk, with the exquisitely fragile lace-work of the net for which it is named hanging from it, gleaming in contrast to the dark, soaked earth and sodden refuse from which it customarily developed. As in various other members of the family, the spores of this fungus were borne in a greenish, viscid mass on its expanded top, with an

odor decidedly attractive to insects. Yet flies, which usually seek such fungi and hence aid in dissemination, were never seen on these Barro Colorado Dietyophoras. Rather, both in the forest and while being photographed in front of the laboratory, all the specimens of Dietyophora were visited constantly by eager expeditions of ants, of a species of Ponerine ant which Professor Wheeler has kindly identified as *Ectatomma ruidum* Roger. No sooner was a specimen of this fungus set down than the ants began to arrive in considerable numbers, and in five minutes as many as thirty or forty would be clambering about the stalk or feeding on the spore mass and could easily be collected for identification. From the legs and mouth parts of ants secured while feeding thus, large numbers of the small rodlike spores with which they had become smeared were readily washed off

into a drop of water and easily recognized under the microscope, so it seems probable these insects in their wanderings help disseminate the fungus.

Among the Ascomycetes certain of the cup-fungi were especially noticeable, the *Cookeinas*, so characteristic of the American tropics, occurring in such profusion along the trails, their stalked cups, a half inch to even almost two inches in diameter, standing out in such brilliant hues of salmon to vermillion against the dark forest floor that they never failed to catch the eye of passing biologists, even when engaged in such high quests as spying on the acrobatic courtship of red-headed manakins or timing the union working hours of leaf-cutter ants. Indeed, the two species of *Cookeina*, *C. sulcipes* (Berk.) Kuntze and *C. tricholoma* (Mont.) Kuntze, enjoyed the rare distinction of being the only fungi of Barro Colorado that visit-



THE FOREST FLOOR

RELATIVELY FREE FROM MUSHROOM-GROWING LITTER, AS THERE WAS NO AUTUMNAL FALL OF LEAVES.



CROSSING GATUN LAKE

IN THE OUTBOARD MOTOR BOAT FROM FRIJOLES,
THE CARETAKER, DONATO, AT THE HELM; BE-
HIND, A DUGOUT LOADED WITH SUPPLIES.

ing ladies with a flair for painting china yearned to immortalize in the undying pigments of their art.

Perhaps second to the colorful *Cookeinas* in conspicuousness should be ranked the dark *Xylarias*, which were represented on the island not by the two or three forms common with us but by an abundance of species, some with elaborate, dichotomously branching fruiting bodies, others with the single perithecial columns variously club-shaped, of diverse sizes, showing lineate or reticulate markings or perhaps with a crown of protrusions at the apex and some densely clustered in irregularly sprawling groups. Also noticeable were

the *Camilleas*, protruding like small, black, gleaming trench mortars from fallen wood, while commonly through the forest, dead branches or logs were marked with the dark stromatic perithecial cushions of *Nummularia* and *Hypoxyylon* or bristled with the hard, black, pinhead clusters of *Phylacia* or *Kretzschmaria*. Occasionally also the minute, orange perithecia of *Corallomyces* or *Nectria*, representatives of the

CONSPICUOUS FUNGI ON DEAD WOOD HERE WERE COMMONLY SPECIES OF *Hexagonia*.

related though more colorful Hypocreales, caught the eye.

The Phycomycetes, the delicate, thread-like and inconspicuous moulds which at home attract our attention chiefly through the unwelcome growth of bread-mould in pantries and bread boxes, are never an obvious feature in the fungous flora of any tropical region, save, perhaps, as the result of their activities shown in gaunt, skeleton groves of coconut trees killed by bud-rot and blasted acres of stunted maize devastated by downy mildews. Yet on Barro Colorado, with a little search one



A WOOD-DESTROYING BRACKET FUNGUS OF SOFT
TEXTURE, ONE OF THE FEW FUNGI OF THE ISLAND
EATEN WITH RELISH BY THE PET MARMOSET
MONKEYS.

could find here and there occasional representatives of this interesting group: Bristling fringes of *Choanephora*, with threadlike, metallic-glistening stalks and dark, spore-powdered heads revealed in the morning light on the fallen, dew-drenched hibiscus blossoms where they had developed during the darkness; occasional delicate tufts of *Mucor* on caterpillar droppings or of *Rhizopus* on fallen flowers and fruits along the trail; incredibly slender, upright threads of



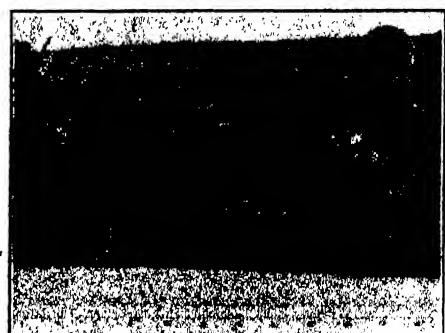
Dictyophora duplicata, THE CONSPICUOUS WHITE "STINK HORN" WITH ONLY FRAGMENTS OF ITS HANGING "LAMP MANTLE" NET REMAINING.

Phycomyces, shining silver in the dark forest on dung of some member of the cat tribe or on bits of flesh clinging to the bones of some animal's kill; short, stubby, pinhead growths of *Pilobolus* on tapir dung in remote tapir wallows in deep and isolated ravines; or an exquisite white lacework of that new genus, *Lymania*, gleaming against dark piles of débris which many years of occupancy by unlovely bevies of bats had left in the cavernous base of a great hollow tree.



A WHITE AGARIC HELPING IN THE DESTRUCTION OF TERMITE-TUNNELED WOOD SAMPLES IN THE "EXPERIMENTAL GRAVEYARD."

The Myxomycetes or "slime-moulds," almost as inconspicuous as the Phycomyces, yet more widely advertised because of their extraordinary life cycle and perplexing affinities with both plant and animal phyla, were fairly common on Barro Colorado. One of the most noticeable species, because of the whiteness and extent of its tufted turf of sporophores, was *Ceratiomyxa fruticulosa*, which occurred not only on fallen wood, as with us, but also on dead branches lodged or suspended in the air where the least disturbance shook off a powder of spores from the extremely fragile, externally spore-bearing fructifications which mark this genus as unique among the Myxomycetes. Also *Lycogala epidendrum* attracted atten-

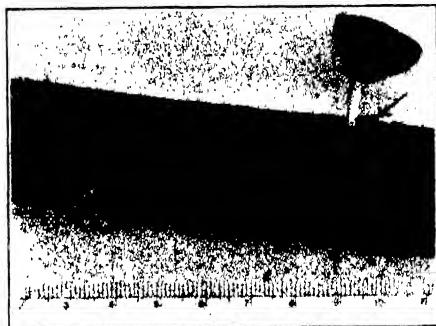


Auricularia polytricha, COMMONLY FOUND ON DEAD WOOD EVERYWHERE THROUGH THE FOREST.



Xylaria comosa, BEARING A CROWN OF PROTRUSIONS ABOVE THE PERITHECTIAL COLUMN.

tion, because of the relatively large size of its clustered, puff-ball-like sporangia; *Hemitrichia serpula*, because of the unusual serpentine labyrinths of its plasmodiocarps; and *Fuligo* and *Brefeldia*, because of the extent of their crusted and trembling aethalia. Moreover, along the trails and deep in the forest common though less conspicuous forms, such as *Hemitrichia clarata*, *Arcyria denudata*, *Lamproderma arcyrionema* and their like, were to be found with a little searching on rotten logs or stumps. Occasionally, in soft, rotten



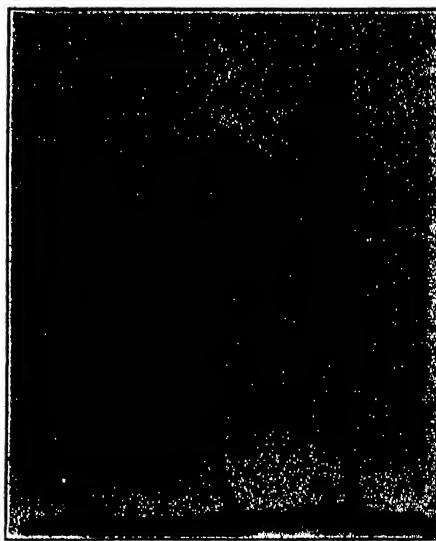
Cookeina sulcipes, ONE OF THE CUP FUNGI WHICH DOT THE FOREST FLOOR WITH BRILLIANT SPLASHES OF COLOR.

wood or dead leaves were encountered the creeping, feeding, protoplasmic plasmodial stages of these organisms, one of which, when brought to the laboratory, successfully developed the clustered sporangia of the fruiting stage of *Didymium squamulosum*.

The *Fungi Imperfici*, here as elsewhere, occurred in profusion, and by hunting could be found in some quantity and in some variety of assortment on practically all hosts and substrata



Hypoxylon Merillii, A COMMON PYRENOMYCETE ON DEAD WOOD ALONG THE TRAIL.



Xylaria grammica, THE MOST CONSPICUOUS OF THE *Xylarias*, WITH COLUMNS AS MUCH AS SIX INCHES TALL.



Camillea mucronata, WHOSE GLEAMING BLACK COLUMNS PROTRUDED LIKE SMALL TRENCH MORTARS FROM WEATHERED LOGS.



Phylactis SUCH AS *P. poculiformis* WERE COMMONLY ENCOUNTERED.

imaginable at all times. The parasitic forms of course were common, for Barro Colorado, although an island paradise, probably harbors as many parasites, although fortunately of a different category, as does New York or Chicago. Moreover, some as secondary invaders followed the tunneling of leaf-mining insects in leaves of a wide variety of hosts; while many as well were saprophytic on rotting stems and branches, not only old friends familiar in New



Hypoxylon SUCH AS THIS (*H. Broomeianum*) REWARDED THE COLLECTOR EVEN DURING THE DRY SEASON.

England, such as the green and velvety *Trichoderma lignorum*, but also rare and beautiful new species of *Rhino-trichum* and similar wood-inhabiting genera. Save in rare instances, however, the *Fungi Imperfetti*, here as elsewhere, do not occur in the open in sufficient profusion to attract immediate attention. There is one, however, which here, as in other parts of the tropics, is a striking exception. This mould, *Monilia crassa*, the imperfect stage of



MANY MYXOMYCETES SUCH AS *Lycogala epidendrum*, COMMON IN OUR OWN WOODS, GAVE AN ASPECT OF FAMILIARITY TO THE BARRO COLORADO FOREST.



OF THE MYXOMYCETES, *Ceratiomyxa fruticulosa*, ALTHOUGH ONE OF THE MOST DELICATE, WAS FREQUENTLY FOUND.

the Ascomycete *Neurospora crassa*, appeared in a strip along the shore where the jungle had been burned off during the dry season to make a clearing for growing bananas. From the scorched wood of charred stumps and blackened branches over this area there appeared overnight great masses of salmon pink tufts of mould, from which powdery

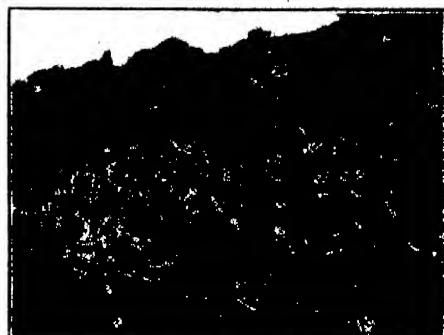
clouds of spores were scattered through the air at every puff of wind or jarring touch. This same striking phenomenon I have seen in Cuba in burned clearings or on sugar-cane after cane fires, and it is reported that a similar profuse growth developed on burned trees in Japan after the Tokyo earthquake and fire and on the forest trees that had been scorched by volcanic eruptions in Java.

It is in the laboratory, however, that such moulds force themselves on one's attention, for in the rainy season conditions are ideal for the growth of many species of such prevalent genera as *Aspergillus*, *Penicillium*, *Alternaria*, *Cladosporium*, especially on leather, on textiles and on composition fabrics. On leather cases, on shoes, on sweatbands of hats, on paste-impregnated bindings, on all kinds of cardboard, powdery discolourations and even bristling growths of mould appeared with magical rapidity,



SHADED LAGOONS FAVORABLE FOR COLLECTING DURING THE DRY SEASON WERE ACCESSIBLE IN THE FAITHFUL CAYUCA, "TOM."

even in some cases over night. Great care had to be taken to prevent collections of dried plants or insects from being ruined thus, and even specimens in such preservatives as alcohol and glycerine were not immune from similar injury. Also it required reasonable care to protect the lenses of cameras and other instruments from the development of minute, delicate traceries of mould which, if allowed to grow undisturbed, in time would actually etch and injure the perfectly polished surface of such valuable glasses; nor could film be left too long unrolled in the camera for fear of unexpected mycelial patches lending a bizarre appearance to the resulting pictures. Even permanent masonry buildings, more protective than our laboratory, were not exempt from similar mould infestation, for during that same season Canal Zone officials were being annoyed by growths of mould which, quite without respect for art, architecture or governmental authority,



THE CONSPICUOUS SERPENTINE NETWORK OF *Hemitrichia serpula* OCCASIONALLY ATTRACTED THE ATTENTION OF THE PASSER-BY.

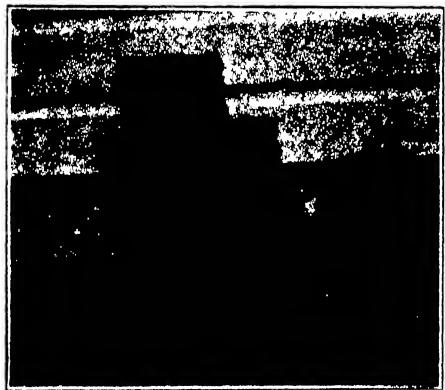
were disfiguring Van Ingen's interesting and impressive murals in the Government Building at Balboa.

On Barro Colorado, as in other tropical places, there is one group of fungi for which one does not have to seek—on the contrary, in diverse and devious ways, they themselves find their way to you, much to your discomfort and regret. These are the obscure fungi which



BROOK BEDS LURED THE COLLECTOR WHEN THE UPLANDS WERE DRY.

parasitize man and hence occupy a place of importance in a fascinating border land of investigation between medicine and mycology. Occasionally, on the chafed, perspiration-soaked skin, despite the daily shower baths that the excellent bathing facilities of the laboratory made possible, there appeared small eruptions of "Dhobie itch," easily cured, and of interest chiefly because of the name which, despite what the ma-



MOULDS FLOURISHED ON LEATHER CASES IN THE SATURATED ATMOSPHERE OF THE RAINY SEASON.



SALMON PINK SPORE PUSTULES OF *Monilia crassa* STOOD OUT BRILLIANTLY AGAINST SCORCHED STUMPS AND BRANCHES IN THE FRESHLY BURNED CLEARING.

rines will tell you, is not derived from "doughboy," and, in spite of what those along the Mexican border aver, is in no way connected with "adobe," but rather, as you probably know from books about India, is derived from a native name of the washerman or washerwoman, because the germs of this fungus may survive and be transmitted by the native methods of washing clothes in the water of ditches or streams and spreading them on the grass to dry.

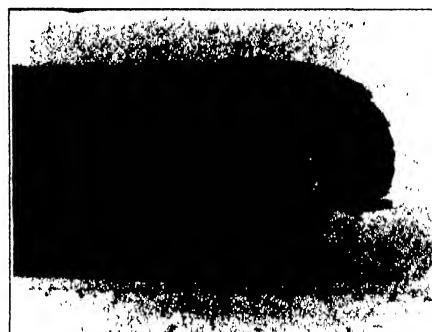
Now and then also itching and even painful cracking between the toes gave evidence that the fungus infection known to the magazine reading public as "athlete's foot" is by no means confined to bridge-playing debutantes or rising young brokers whose exercise, according to the advertisements, consists in reaching for a cigarette, or climbing into a Rolls Royee, but attacks the humble and hard working biologist as well. After vainly attempting a cure with the greenly fragrant modified horse liniment press-proclaimed as specific, the harassed victims successfully overcame the trouble with Whitfield's ointment or other like compounds found effective by reputable dermatologists and rendered up thanks that only these relatively mild fungous afflictions are known to the island and not such medico-mycological horrors as Madura foot, blastomycosis or sprue.

As the rains lessen and become infrequent in late November and early December, and by January and February the dry season is well advanced, striking changes are noticeable in the fungous population of Barro Colorado, for although "What Men Live By" may require exposition in books and essays so numerous as to indicate some difference of opinion, it is in general a certainty that what fungi live by is warmth, food and, above all, moisture. With the advance of the dry season fungi become less conspicuous, yet Barro

Colorado still offers opportunities to the mycologist, for in deep brook beds, along the edge of the lake, and in the numerous shaded lagoons of long-drowned gullies, the proximity to moisture prolongs the growing season of certain fungi, while in the lake itself that fascinating group of the aquatic Phycomyctes continues to flourish, even though the water may reach a temperature of 85°, and logs or matted islands of vegetation floating on the surface may support fungous growth unchecked by the general drought of the inland slopes. Also at the height of the dry season hardy, slow-growing Pyrenomyctes still persist, and fallen remnants of succulent flowers or fruits which mark the burgeoning of the drier months may furnish a temporary moisture to support the brief periods of growth of delicate, evanescent moulds. Even during the dry season, however, a few inches of rain fall in occasional showers, which bring about remarkable changes in some of the persistent xerophytic Auriculariales or jelly fungi. These, dried to hardened, cartilaginous, inconspicuous layers or nodules, rapidly take up moisture and appear as if by magic as rubbery or gelatinous fungous growths, easily seen by the passer-by.

Having noted that of the three prime requisites for fungous development warmth, food and moisture—it is moisture which on Barro Colorado is chiefly the limiting factor, it is worth mentioning, perhaps, that there are some rather interesting limitations to definite food supply and definite substrata. Most of the fungi encountered, of course, are catholic in their tastes, occurring on almost any forest refuse, woody or soft, but some were definitely restricted to certain substrata and never found under any conditions on any other material. For example, the common occurrence of *Xylaria ianthino-velutina* Mont. on the

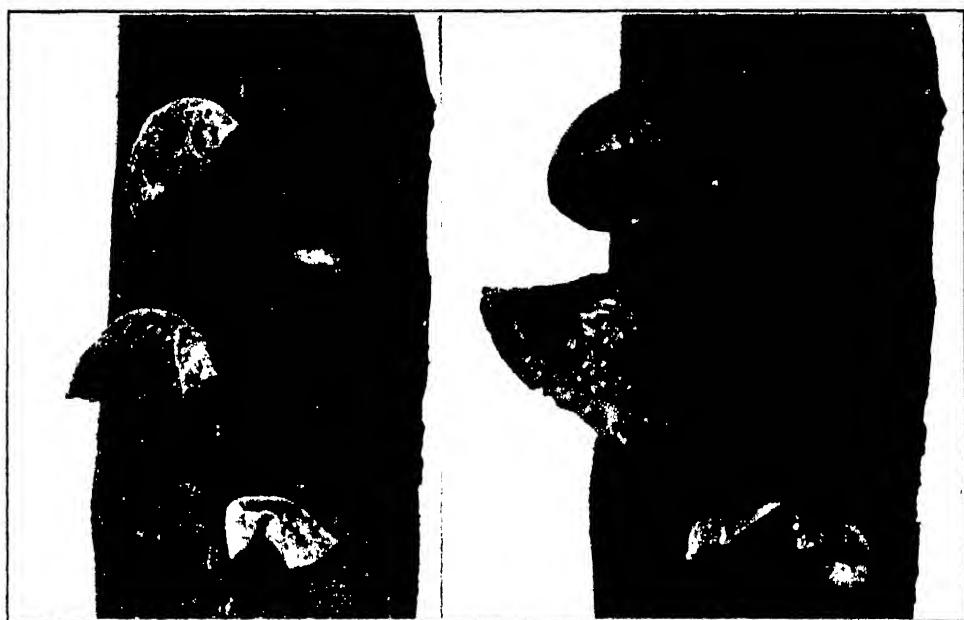
fallen pods of *Apeiba aspera*, which lie like misplaced sea urchins on the forest floor, was notable, for this species of *Xylaria* was never found on any other substratum. Also a brilliant cinnabar and golden colored agaric, found commonly on recently fallen pods of *Bombar barigou* in January, was never seen on anything else nor even on these pods after they dried and shriveled later in the season. Then, too, the tall, dark,



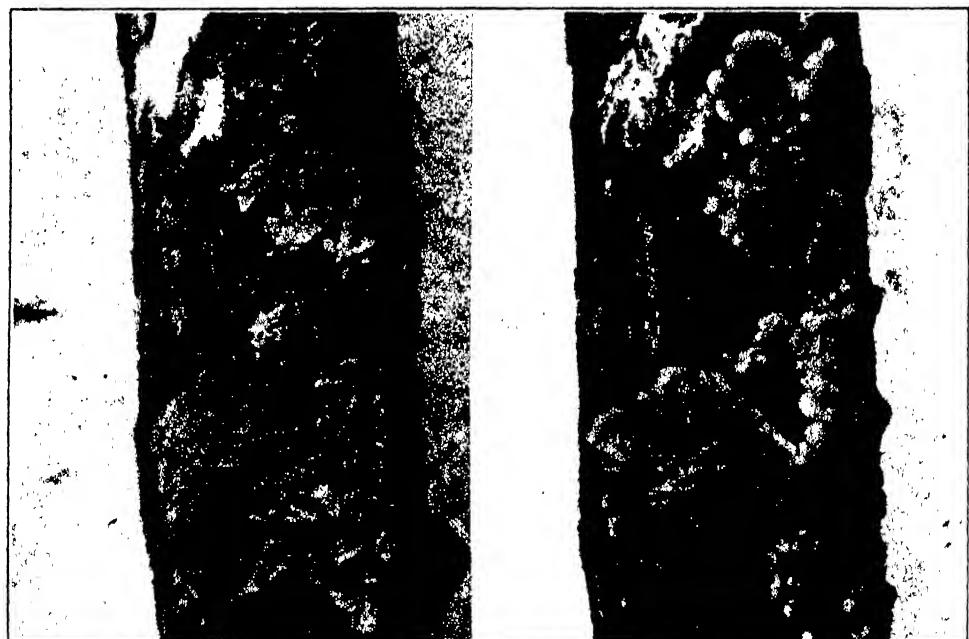
Entonaema mesenterica COULD STILL BE FOUND DURING THE DRY SEASON.



Phillipsia Domingensis, ITS BUFF CUP LINED WITH CRIMSON, WAS A LUCKY FIND IN A DEEP RAVINE DURING THE DRY SEASON.



HARDY *Auricularias* ENDURING THE DRY SEASON (LEFT), EXPANDED RAPIDLY AFTER SHOWERS (RIGHT).



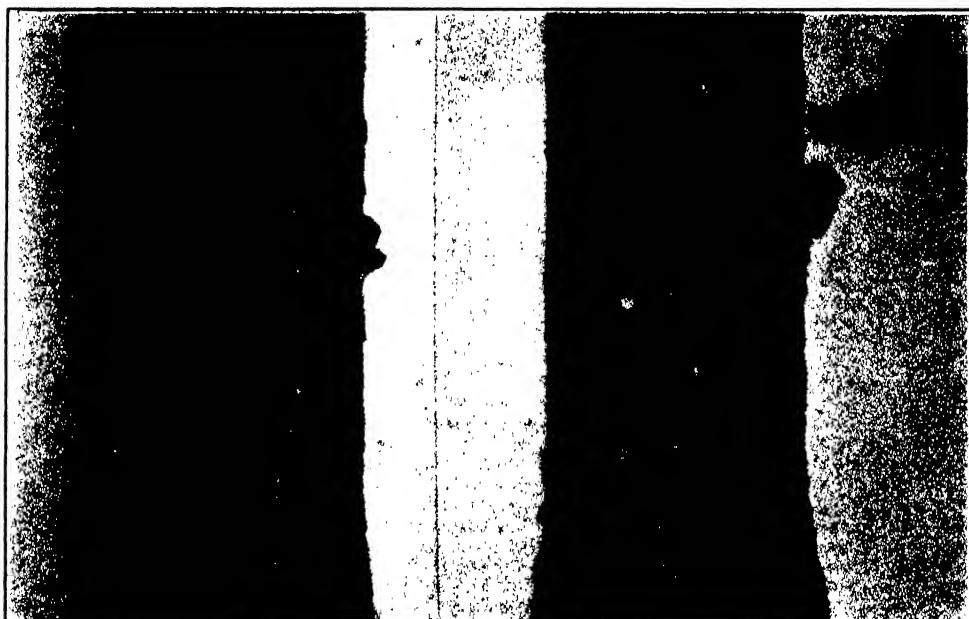
Auricularia mesenterica BEFORE AND AFTER A SHOWER, SHOWING THE FANCED RESEMBLANCE TO AN EAR THAT HAS LED TO ITS COMMON NAME "OREJAS."

fuzzy parasols of *Lentinus velutinus* Fr., seemingly sprouting from the earth along the trails, were invariably found to originate from small, hard, knotty pieces of heart wood, the persistent remains of branches otherwise disintegrated, long buried in the soil.

With so numerous an insect fauna on the island and so many fungi, one can encounter many instances of the interesting interrelations between these two fascinating groups of organisms, and it

of fish-hook spined leaves, specimens of *Septobasidium* were found near the tips of somewhat *passé* leaves. This was apparently a new species of this interesting genus, awaiting the attention of Couch, whose work has brought out the beautiful interrelationship of this fungus and the scale insects associated with it.

The growth of certain fungi on insects as parasites is perhaps a less conspicuous feature here than in temperate re-



JELLY FUNGI, INCONSPICUOUS WHEN DRY, APPEARED AS IF BY MAGIC AFTER OCCASIONAL SHOWERS.

is to be regretted that this intriguing field of investigation has not been pursued further on the island. Wherever the nests of leaf-cutting ants were cut open, the curious, knobby fungous growth that is cultivated by the Attas could be found, while the trails of leaf-mining insects and galleries of wood-tunneling termites gave evidences of interesting fungous associations. Occasionally, also, on the wild pineapples (*Ananas magdalense*), which in the low ground of the forest form dense thickets

gions, for, although entomogenous fungi were sought on Barro Colorado, very few were found. In one case I encountered a small cockroach covered with a pale, gray-green, powdery growth of *Metarrhizium*, while Curran, during his collecting of *Diptera* and other insects, gathered in not only further examples of this green muscardine fungus but also an *Isaria* on two small bugs and a beautiful, slender, though immature *Cordiceps* on a beetle. The Entomophthoraceae, although sought par-



ONLY ON THE FALLEN PODS OF *Bombax barigou*
WAS THIS GOLDEN AND ORANGE AGARIC FOUND.

ticularly, either were rare or else escaped intensive search, for I found no specimens nor did Curran, even though



SUCH ENTOMOGENOUS FUNGI AS *Metarrhizium*
WERE SELDOM ENCOUNTERED.

he intensively collected hundreds of *Diptera*, which in temperate regions are relatively common hosts for these parasites.

In tropical regions such as this with abundant fungous flora comprising many conspicuous noticeable members, it is always of interest to learn to what extent the observant though not scientifically trained people of the vicinity recognize fungi by vernacular names or make use of them in food, medicine or industries. In general, here on the island, as elsewhere in the vicinity, one encounters only a scanty vocabulary of vernacular names. Men of some education, such as Donato, the versatile and indispensable caretaker, knew the Spanish word "hongo" for fungi as a whole, but lacked names for the many very different types; while uneducated workmen did not have any distinguishing vernacular names for fungi in general, much less an assortment of different words for different kinds. The only common word in general use seemed to be "orejas" or "orejas de palos pudridos," merely the Spanish for "ears" or "ears of rotten stumps." This Spanish name "orejas" is of some interest, as it is based on a resemblance which has led to a number of similar names in various languages. Here it seems to be applied particularly to the gelatinous *Auricularia*, the common name of which in English is "Jew's ear" or "Judas' ear" fungus, the same root to which the scientific name of the species, genus and family gives formal Latinized recognition. For the *Auricularia mesenterica* common on Barro Colorado, with its general shape of the human ear, its elastic, cartilaginous texture, veined or folded surface, and warm brown color, this is indeed an apt characterization. The term is not restricted to this type of fungus, however, but is used for Hymenomycetes in general, whether

smooth or with gills or pores, sometimes followed by a qualifying adjective such as "blanco" or "grande." It is interesting that with much the same appreciation of this resemblance some of the natives of the Philippines call such fungi "oong," meaning "ear," while in other languages of Malay origin like words of similar meaning are used. In Cuba also such fungi quite generally are called "orejas," but in addition the Guajiros or country people employ the word "guataca," which merits further explanation. The "guataca," strictly speaking, is the heavy hoe used for digging out grass or other weeds from fields of cane or corn, and, being a typical and indispensable instrument of the Guajiros, enters into their slang or argot in that a person with large and prominent ears is said to have "guataeas," which is equivalent to the phrase "shovel ears," which one occasionally hears in our own South; while flattering or otherwise working a person to obtain something is usually called "guataqueria," literally "hoeing," which offers an amusing similarity to our sophisticated phrase "gold digging."

In contrast to the scarcity of names used for fungi by the people of the Barro Colorado region, there is a long list of colloquial names applied to flowering plants of the locality, some of them strikingly picturesque, clever and colorful. Indeed, the same aptness for simile led to the immediate invention of equally vivid names for fungi, when these were called to the attention of the natives. For example, when shown *Dictyophora*, with its white lace-like net, they immediately called it "hongo de camiseta" or "hongo de camiseta de lamparillo," literally "lamp mantle fungus," deftly expressing the resemblance which the delicate, hanging veil bears to the common Welsbach gas mantle. Nor were they slow to invent in

Spanish or vernacular aptly characterizing names of untranslatable obscene significance, which certain resemblances of the Phallales have evoked in various languages since the most ancient times.

The small recognition of fungi in vernacular names is paralleled by the scanty notice which they receive in other respects throughout the region. Apparently they are never used for dyeing, tanning or tinder, seldom eaten, and



A SLENDER *Cordyceps* ARISING FROM THE DEAD BODY OF ITS BEETLE VICTIM.

little used in medicine, although I was told that in the interior further back from the Canal Zone the people, in a rude practice of first aid, frequently use a fungus, which from the description is apparently a puff ball, applying the mass of spongy tissue and spores to a cut to "make the blood stick," as they say, a practical use for such fungi by no means limited to Central America, but once common in England and Europe and even now occasionally followed in our own rural regions.

From the very nature of fungi there is less perhaps of romance and danger in their collection than in seeking wild animals or orchids, yet even in collecting fungi in this tropical jungle environment of Barro Colorado there are moments of excitement. Once, for example, when reaching down to secure an unusually luxuriant growth of *Xylaria consociata* Starb. on a rotten log, I was checked by an exclamation from my companion, Dr. Dunn, who pulled out the trusty Game-Getter gun and shot a six-inch tarantula which lurked, black, hairy and dangerous, poised in an almost perfect concealment among the black sprawling fungus growth a few inches beyond the specimen toward which I was reaching. There were also instants not without hazard in collecting along the coast line of the island in a small and delicately balanced cayuea, for the high waves, which during the dry season were soon piled up by the

wind blowing steadily across the broad stretches of the lake, not only in themselves rendered navigation in a dugout exciting to say the least, but when augmented by the wake of large steamers passing close by required quick and strenuous work to keep from being overturned. These same waves from passing steamers produced one unexpected effect, for as they rushed into some of the narrowing inlets so located as to receive their full force directly, their power increased as the inlets narrowed until in the little muddy brook beds at the end of such inlets, small tidal waves as much as two feet high would come rushing onward carrying everything before them. These proved a great surprise to an unwary investigator who, standing in an apparently dry brook bed with material scattered about and a camera set up, would suddenly, without warning, find a rush of waves bearing down upon him to swamp everything



STUMPS OF THE DROWNED FOREST, HERE REVEALED BY LOW WATER, MADE NAVIGATION IN A DUGOUT HAZARDOUS.



SEA URCHIN-LIKE PODS OF *Apeiba aspera*, THE ONLY SUBSTRATUM ON WHICH *Xylaria ianthinovelutina* WAS FOUND ON BARRO COLORADO.



THE TOUGH, VELVETY PARASOLS OF *Lentinus reticulatus* ALONG THE TRAIL INvariably AROSE FROM HARD, KNOTTY REMNANTS OF BURIED BRANCHES.

and leave him grabbing frantically to rescue the well-soaked relires which otherwise they would have carried away.

It can be seen that the island is a rich collecting place for the mycologist, for the fungi on which this brief and fragmentary account is based were encountered only incidentally, since I was engaged in the study of a small, specialized group of submerged aquatic Phycomycetes and did no intensive collecting of other groups, merely picking up what I encountered in tramping the trails or exploring the inlets and gullies around the island shore. Such an account as this, therefore, is in no sense a representative record of the fungi of the island.

It touches not at all on the innumerable leaf-spotting forms or the sooty moulds that occur with such frequency that one leaf has been said to furnish some of our colleagues with enough material for one monograph, two students' doctorate theses and four short papers. It neglects equally the smuts and rusts, it ignores the innumerable manifestations of fungous associations with algae in the brilliant and many-formed lichens in which the jungle abounds, but, although scanty, it may serve to give to others some idea of the abundance and interest of the fungi which await further study in this untouched island paradise for biological investigation.



MOUNT MCKINLEY, ALASKA
THE HIGHEST OF THE MOUNTAINS ON THE NORTH AMERICAN CONTINENT, 20,300 FEET.

The Scientific Work of the Government of the United States

THE ALASKAN WORK OF THE UNITED STATES GEOLOGICAL SURVEY

By PHILIP S. SMITH

CHIEF ALASKAN GEOLOGIST, U. S. GEOLOGICAL SURVEY

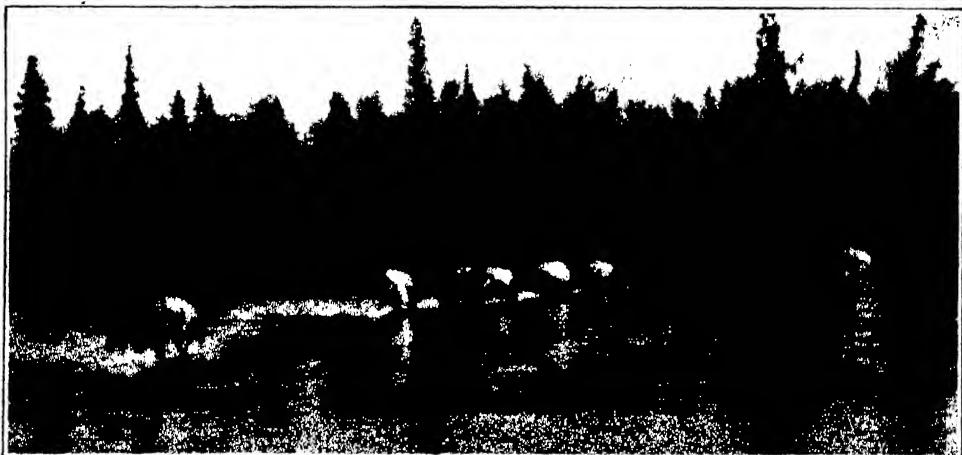
WHEN Alaska came into the possession of the United States through purchase in 1867 it was an almost unknown country whose resources were thought to consist mainly of wild animals and untenanted land. As time went on other sources of wealth were found in it and exploited. Most of these finds were more or less intimately involved with geographic problems or with mineral resources, so that the United States Geological Survey early became officially concerned with Alaskan developments, though notable contributions to knowledge of the country were made by many other government organizations, such as the War Department, Navy Department, Bureau of the Census and Revenue Cutter Service, as well as by many private organizations and individuals.

As early as 1889 one of the members of the Geological Survey, attached to an expedition of the Coast and Geodetic Survey, traversed much of the Yukon from the mouth upstream and thence went overland to the coast at Dyea. In 1890 and 1891 one of the Survey geologists made extensive explorations in the vicinity of Mount St. Elias and almost reached the top of that 18,000-foot giant. In 1891 another of its members made a notable trip through the unexplored country inland from Juneau and thence by a devious route to the Copper River, and several extensive contributions to knowledge about Alaska were made by other members, either as part of their official duties or when attached to other enterprises.

The discovery of the fabulously rich gold fields of the Canadian Klondike and the impetus that that discovery gave to the gold seekers to extend their search into adjacent parts of Alaska resulted in 1898 in the Geological Survey making special efforts to supply reliable information to these pioneers, through sending out numerous field parties of its own and through collating and publishing the available information accumulated by others bearing on Alaskan matters falling within its field of endeavor.

This marked the real beginning of a distinct Alaskan organization as a unit of the Geological Survey, though administratively it was not officially designated as a separate entity until 1903, and it was not formally recognized as a major subdivision of the Geological Survey equivalent in rank with the other major branches, such as those dealing with geology, topography and water resources, until 1922.

The principal object of this unit, as tersely stated in the appropriation item by which funds for its support are granted by Congress, is "investigation of the mineral resources of Alaska." This, then, has been the prime aim of its endeavors and the focus of its studies, but the pursuit of this aim has involved many contributory undertakings that may not at first thought seem related to the major problem. When the work was started much of Alaska remote from the coast and from the main highways of travel—the large rivers of the interior—was so little traversed that even the



RIVERS THAT MUST BE CROSSED ARE EVERYDAY ITEMS IN THE PROGRESS OF THE ALASKAN SURVEYS

INDEED THE CROSSING OF A PEACEFUL STREAM LIKE THE ONE SHOWN IS REGARDED AS OF NO MOMENT AND MEN AND ANIMALS FORD IT WITH EASY UNCONCERN.

geographic character of many parts was unknown. Therefore, from the very beginning a pertinent part of the Geological Survey's job was the determination of the most suitable routes to the reported gold strikes and the furnishing of general information as to the conditions that prevailed there. Vast areas were entirely unexplored, so that determination as to whether or not they held

promise of mineral deposits of significance awaited the prospector and the investigation of the Survey. Even for the best-known areas the available maps were usually so crude and inaccurate that few of them were reliable guides for the prospector, and practically none of them were suitable bases for use in the field investigations of the known mineral deposits. Therefore, as an in-

dispensable part of its work on mineral resources, the Alaskan unit began the topographic and geologic mapping of the Territory. In the more settled regions of the States the topographic map is to be used for many engineering purposes and is therefore made on a fairly large scale, but in Alaska, in the interests of economy and to meet only the most pressing needs, the mapping was done principally on an exploratory scale (8 miles to the inch or smaller) or a reconnaissance scale (4 miles to the inch). As a result of the surveys that have been made by the Geological Survey during the last 35 years, more than 260,000 square miles has been surveyed geologically and 277,000 square miles has been surveyed topographically. These areas represent respectively about 44 per cent. and 47 per cent. of the 586,400 square miles embraced within the territory. Much less than 1 per cent. has been surveyed even to date on as large a scale as a mile to the inch, the usual detailed scale adopted for comparable work in the states proper.

In making these surveys the government geologists, topographers, and engineers have necessarily had to conduct their work so as to fit the field conditions encountered. Thus many of the parties have covered the areas assigned for their investigations by the use of pack trains, consisting of as many as a score of animals loaded with the equipment and supplies required for months of traveling away from all centers of replenishment. Others have traversed thousands of miles of streams and hundreds of miles along the coasts in fragile canoes, skiffs, poling boats or other river craft. Others, especially those working in southeastern Alaska, have carried on their surveys from power launches that not only served as the means of transportation but also afforded shelter and home to the parties in the field. Still others have used dogs extensively for the transportation of their supplies—in the

winter driving them attached to the freight sleds, in the summer hitching them to the tow-lines of the boats to help haul on the upstream journey or loading their backs with packs for cross-country travel. In fact, practically all means of transportation, from the swift-flying airplane to the slow, laborious plodding of man with a heavy pack of supplies and equipment on his back, have at different times and on different expeditions been used by the Survey's explorers as they have wrested the knowledge of the far-off parts of Alaska and acquired the data from which their maps and reports have been constructed. Throughout thousands of miles the trails and routes of these explorers are still the basis for the only definitely recorded annals of the country, though doubtless others who have left no trace of their travels and discoveries have also visited some of the remote regions.

Working under such conditions, the members of the field force of the Alaskan branch must necessarily be all-round outdoor men. Familiarity with field conditions and capacity for personally undertaking the accomplishment of their technical work under whatever conditions they may encounter are taken as much for granted as that the ordinary citizen will be able to find his way around his home town. It is the proud boast of the Alaskan branch that in spite of the hazards its men have faced and overcome, none of its parties has ever lost a man or had one permanently injured. To paraphrase a combination of advertising slogans, "They get there and bring back results."

This sort of pioneering, however, is only one phase of the Geological Survey's investigations, and in a way it may be likened to a preliminary sorting by which the more promising areas for further study are separated from those that do not appear to have resources that require such immediate attention. In other words, as a result of these pre-



TRANSPORTING EQUIPMENT

WHEN ALL OTHER MEANS OF TRANSPORTATION PROVE IMPRACTICABLE THE MEMBERS OF THE ALASKAN PARTIES MUST PACK ON THEIR OWN BACKS ALL EQUIPMENT AND SUPPLIES NEEDED TO PUT THROUGH THE WORK.

liminary explorations the geologist attempts to discriminate areas of moderate extent that appear most likely to contain mineral deposits of value. How is this determination made? There is no royal road to the answer. It involves the application of every phase of geologic science, and ability to make it can be acquired only by long and thorough training and wide familiarity with the various types of mineral deposits throughout the world and the conditions that contributed to their formation. Coupled with that knowledge must be keen observation of all the features in the region that is being studied, so as to appreciate similarities to favorable localities or differences that may be of significance. The Alaskan geologist must be always alert to grasp the facts, so that he is not hesitant in adopting new views nor yet hasty in embracing the novel simply because it is new. A sane balance and a reliance on carefully weighed evidence are obviously indis-

pensable in arriving at a sound judgment. Nor is a judgment once reached necessarily final, because each new advance in science and each new development yields new criteria and new data by which old judgments must be re-tested and, if necessary, revised.

To adapt the old saying "Physician, heal thyself" to this problem, it is evident that before the geologist can be of much help in suggesting where new mineral deposits may be found he must be well acquainted with the region about which he is to venture a prediction. He must, therefore, have scrutinized with especial care all its mines and the places in it where signs of valuable minerals have been found, so as to become thoroughly familiar with every fact bearing on the conditions under which the deposits occur. He is then in a position to formulate his ideas as to the places where extensions of those conditions are likely to be found and can thus direct his search toward testing the accuracy of these ideas and, if they successfully stand that test, make them known to the public he aims to serve.

However, these investigations are not limited to studies in the field, for the collections of rocks and minerals and the voluminous notes and records must be subjected to further studies in the laboratory, and the literature on related subjects must be examined and balanced against the observations in hand. This work may involve chemical analyses or microscopic tests of the ores, critical diagnosis of the fossils, and perfecting of the field sketches, maps, and notes; in fact, every line of research is utilized that may contribute to a more accurate and thorough comprehension of the problems involved and to the working out of their answers. As a result, more time is usually required for the digesting and putting into order for publication these records of observation than for their original collection in the field.

Although all the Alaskan work is

focused on the investigation of the mineral resources of the territory, the items that contribute to that subject are diverse, and many of the by-products of these studies are of significance. Whatever pertinent information can be obtained from other sources is of course utilized, but in the progress of the Geological Survey's own studies in remote and unexplored districts much general information not otherwise available is obtained, relating, for example, to various climatic elements, such as rainfall and temperature, or to the distribution of timber that might be utilized in mining, or to the native animals that might be used for supplying food. Some of the technical by-products of these studies which may not be directly connected with the prime object of the investigations are the recognition of some of the special geologic processes that are active in higher latitudes than those with which most geologists are familiar; the collection of fossils that furnish an insight as to many of the conditions that prevailed in the region when they were parts of living organisms; and evidences of past glaciation that smothered large tracts in northern United States and in part affected Alaska also. In fact, the general information obtained by the Alaskan field force covers so wide a range that often persons write to the Survey for information wholly unrelated to its official investigations—for instance, to inquire for persons who have disappeared and whose whereabouts are unknown except that they proposed going to Alaska—and strange to say, the desired information has sometimes been obtained from the memory or notebooks of one of the Survey staff.

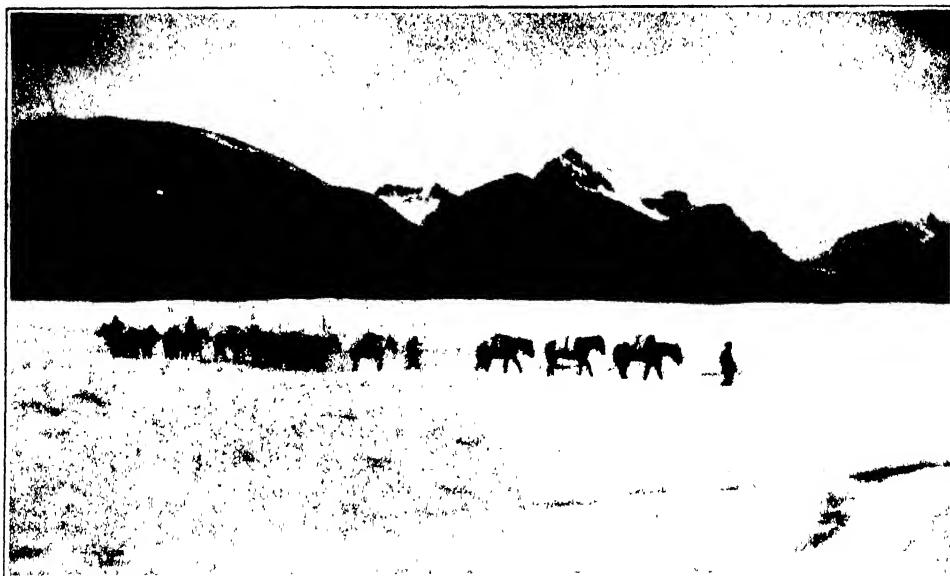
The mere collection and assembling of information regarding Alaska is, however, of little general significance, unless the information is made known. The Geological Survey, to meet the duties of its trust as the consulting geologist to

the people of the United States in geographic matters, must make its findings that are of significance to them readily available. This is done principally through its formal reports and general notices and through specific answers to thousands of widely scattered correspondents. Already more than 400 separate reports regarding different Alaskan districts or subjects investigated by the Survey have been printed and widely distributed. Almost all these reports contain not only textual descriptions of the subjects treated but also graphic representations in the form of maps. The more comprehensive reports also contain other illustrative material, which gives vividness and clarity to certain phases that can be best explained by that means.

From year to year the specific work undertaken by the Alaskan branch differs both as to its character and as to the areas in which it is done, so as to meet best the current needs of the mineral industry and to utilize most effec-



A GEOLOGICAL SURVEY'S GEOLOGIST
MAKING OBSERVATIONS AS TO THE RICH GOLD-BEARING PLACER DEPOSITS IN ALASKA.



A GEOLOGICAL SURVEY OUTFIT OF MEN AND HORSES
CROSSING RUSSELL GLACIER, ONE OF THE STREAMS OF ICE IN THE EASTERN PART OF THE COPPER
RIVER VALLEY, ALASKA.

tively the funds and personnel at its command. An idea of the general type of work done may be obtained from the following summary, which outlines the ten projects chargeable to funds directly

appropriated to the Geological Survey that are in progress for the current year. Seven of these projects involve both field and office work and are as follows: Reconnaissance topographic mapping in



RIDING BEHIND THE DOGS

WHILE BUNDLED UP WARMLY AND ON A GOOD TRAIL WITH A LIGHT LOAD IS EXHILARATING FUN, BUT THERE IS SELDOM A CHANCE TO RIDE ON THE GEOLOGICAL SURVEY SLEDS WHICH MUST BREAK THEIR OWN TRAILS AND ARE USUALLY HEAVILY LOADED, SO THAT THE MEN WORK HARDER THAN THE DOGS TO MAKE THE NECESSARY MOVES.

the Wrangell district and adjacent parts of southeastern Alaska; mining studies in the Taku district, near Juneau, and at other points in southeastern Alaska; reconnaissance topographic surveys in the mountains at the head of the Copper River and in isolated unmapped tracts adjacent to the Richardson Highway between Valdez and Gulkana; reconnaissance geologic surveys in the Tonsina district, in the west-central part of the valley of the Copper River; reconnaissance topographic mapping of the northern part of Kodiak Island and adjacent islands in southwestern Alaska; a geologic reconnaissance of parts of the Alaska Peninsula and the Aleutian Islands, in connection with an expedition sent by the Navy Department into that region; and general studies of recent mining developments throughout Alaska. The three projects for the present year that involve principally office work, though they are based in large measure on results of field work, are the annual canvass of mineral production for the calendar year 1932; the completion of a comprehensive report on the geologic features and mineral resources of the whole region in central Alaska lying between the Yukon and Tanana Rivers, which will summarize and correlate the results of more than 30 years' field work; and the general work performed by the main office of the branch and the field offices at Juneau and Anchorage, Alaska.

In addition to the projects listed above the Alaskan branch conducts all the investigational work on mineral resources financed by the Alaska Railroad under its authorization "to ascertain the potential resources available that will affect railroad tonnage." This work for the current season involves planning and technical supervision of two projects directed toward determining by means of diamond drilling, the resources of two

coal fields adjacent to the Alaska Railroad; a combined geologic and topographic party to survey and examine more than 1,000 square miles of hitherto unmapped country lying near and on the flanks of Mount McKinley, in the Chulitna Valley, in central-southern Alaska; and a resident geologist at Anchorage to act as technical adviser to the manager of the Alaska Railroad. The Alaskan branch is also intrusted with the conduct of all field work required in connection with the administration of the mineral leasing laws so far as they relate to Alaska and are performed by the Geological Survey, though this work is financed by an allotment of funds from a separate appropriation item.

Why is the work outlined above undertaken by the government? This is really a double question, for by implication it raises both the query whether the work itself is worth doing and, if that is answered in the affirmative, the query why it should be done by the government rather than by private individuals. It would be presumptuous for a person closely connected with the work to attempt to dispose of the first part of that question. Suffice it to say that there is a continuous demand for the Survey's past publications on the different mining districts and an insistent call for it to undertake the exploration of additional tracts that have not yet been reported on, and that throughout Alaska at least the Geological Survey has a most enviable record of accomplishment, at an extremely economical cost. I know of no group of government employees who are recognized by the public they aim to serve as having more indefatigable industry, greater pioneering ability, higher professional skill, or more thorough integrity than the group of past members of the Survey's Alaskan unit.

If, then, we may accept the fact that the work of the Alaskan branch has re-



MEMBERS OF A GEOLOGICAL SURVEY PARTY

LINING THEIR BOATS LOADED WITH THEIR SEASON'S EQUIPMENT AND SUPPLIES UP ONE OF THE SWIFT-FLOWING RIVERS OF NORTHERN ALASKA.

ceived the indorsement of the people in general and financial support through Congress in spite of various economy programs for nearly 35 years, as warrant for assuming that the project of itself has merit, we may attempt to answer the second part of the question—namely, Why is this the government's job? Much more than nine-tenths of Alaska still remains absolutely in the possession of the national government. Therefore the government's own interest as landlord would alone suffice to necessitate its undertaking the work. Knowledge of the physical features of its holdings and of their resources that may be of value is obviously indispensable for intelligent development, profitable utilization and effective administration. A private landowner would be regarded as extremely lacking in business sense if he failed to determine the bounds and resources of his estate and had not formulated a wise plan for its development. If the private owner hoped to dispose profitably of parts of his property to

others he would necessarily take those steps if he expected to be successful. The government is conducting a vast business in disposing of its lands, and its responsibility goes beyond that of any private owner, for it endeavors to make sure that the resources of these lands are wisely exploited.

Although in the foregoing statements emphasis has been placed on the government's own need for information of the type furnished by the Alaskan work of the Geological Survey, that need is of course not something wholly apart from the needs of its citizens. On the contrary, the "Government" and the citizens are one, and their interests and needs coincide rather than run at cross purposes. For that reason the same type of information regarding Alaska's mineral resources that the administrators of the government's activities need is also useful to the individual men and women who see Alaska as a land of opportunity for their endeavors. Without their private enterprise to develop these re-

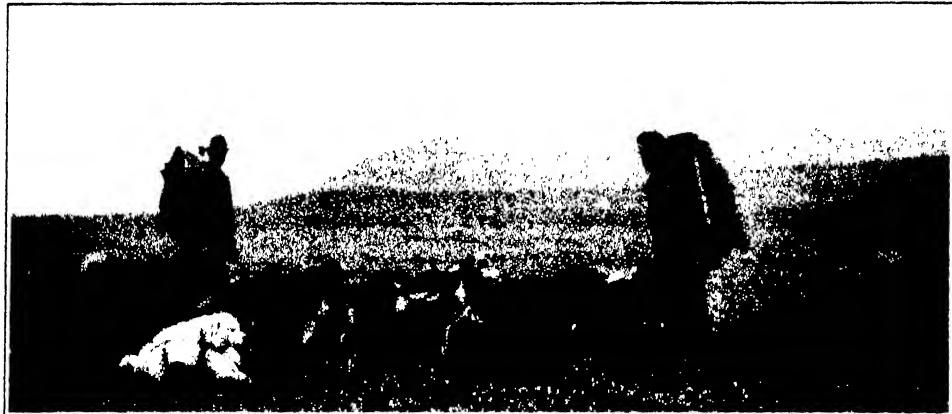
sources the many facilities which the government provides and, in fact, the whole of the government's activities in the Territory would become inconsequential and of little avail. Of course, some of this information might be collected by equally proficient geologists and engineers in private employ, but that would lead to considerable waste effort and duplication because, as a rule, the results of such examinations are not made public, and the same work would be done over and over again by each succeeding examiner. But some of the work could not be done by persons in private employ because the government geologists have access to many sources of information that usually are not available to private engineers. For instance, one of the projects carried on under this item each year is the comprehensive canvass of the output of the different mineral commodities. The production of gold from an individual mine is of itself a private matter that is regarded as more or less a secret, and yet knowledge of the total amount of gold produced from all the mines in different districts

or of different types is significant to world policies as well as those of more local circles. The collection of such information necessarily must be carried on by some such organization as the Geological Survey, which can be relied on to respect the confidential character of the information supplied and has so comprehensive a knowledge of the mining industry throughout the Territory that its findings are complete, continuous, and reliable. However, although many types of mineral investigations can be made best by geologists of an official organization like the Geological Survey, there are unquestionably others that such an organization can not as well undertake. In full realization of this distinction the Geological Survey refrains from entering any of the enterprises that can be better done by others. So scrupulously has this policy been adhered to that such adverse comments as have been heard indicate that some companies and individuals feel that the Survey does not go as far in certain lines as they wish, rather than that it oversteps appropriate bounds.



TOPOGRAPHER WITH ASSISTANTS ON STATION

USING PLANE TABLE AND ITS ACCESSORIES TO MAP THE MOUNTAINS AND VALLEYS OF ALASKA.



MEN AND DOGS WITH THEIR PACKS

LOADED FOR CROSS-COUNTRY TRAVEL IN THE CONDUCT OF THE EXPLORATORY SURVEYS MADE IN MOUNTAINS OF NORTHERN ALASKA BY THE GEOLOGICAL SURVEY.

To write of the Alaskan branch only in terms of the past might leave the impression that its days of strenuous labor are over and that it has fulfilled its mission. Such an impression, I believe, is not warranted, for as I see the future needs there is and will be an increasingly greater demand for the kinds of service it is qualified to give. Less than half of the vast area of Alaska has been mapped and investigated on even reconnaissance standards, so that there is more than 300,000 square miles, or an area about 35 times the size of Massachusetts, that has not been surveyed, and probably in at least two thirds of that area there are tracts which may contain mineral deposits that are worthy of development. In addition, there is a continuing need for more detailed and precise studies in many of the camps that were only cursorily examined in the course of the earlier exploratory or reconnaissance surveys. Probably in most of the long established camps the more obvious deposits have already been found, so that to bring to light the more obscure and yet perhaps equally worth-while deposits that may be developed in the future will require far more critical and intensive

work. The type of information that was adequate for the pioneer who mined in a small way is no longer exact enough for the larger operators whose preliminary outlays run into millions of dollars. Nor is the technique of searching for ore deposits at a standstill, for advances are being constantly made, and these more refined methods and equipment are furnishing tools by which problems that were beyond the attack of earlier geologists can now be undertaken with considerable assurance of obtaining results of significance. The Territory itself is constantly being more and more opened up, so that districts which were once remote are becoming accessible, costs in them are being lowered, and therefore some of their deposits that formerly were not worth considering are fast nearing the limits of workability. All these things clearly indicate that if it proves fit to grasp the larger opportunities offered, the Alaskan branch of the Geological Survey will continue for a long time to find problems relating to the mineral resources of Alaska which will require for their solution its best efforts and its utmost skill.

ON THE RESEARCH WORK OF THE U. S. WEATHER BUREAU

By Dr. W. J. HUMPHREYS

WEATHER BUREAU, UNITED STATES DEPARTMENT OF AGRICULTURE

By act of Congress it is the duty of the U. S. Weather Bureau to keep continuous records of the state and condition of the sky and the air at many places, to issue forecasts, based thereon, of the temperature, wind, rain and other weather elements of the morrow and the day after, and also from these records to discover the climatology of each and every portion of the country.

To perform this public service at all satisfactorily it was necessary first to provide for obtaining reliable records of the temperature of the air, degree of humidity, amount and kind of precipitation, wind direction and velocity, cloudiness and sunshine, and also very accurate measurements of that special condition of the atmosphere, namely, its pressure, which though inconspicuous to our senses nevertheless is so related to weather changes as to be exceedingly valuable to any one who, from to-day's weather, forecasts that of tomorrow.

Thus was necessitated a long series of investigations that had as their object the securing of records accurate enough for the uses to be made of them, with apparatus inexpensive, sturdy, durable and convenient. Of course those without experience in such matters might think that this would be the easiest sort of thing to do. For instance, one who has not tried it naturally is cocksure that an accurate measurement of the amount of precipitation is the simplest thing in the world to effect, and indeed rough measurements of it are easy to make, and have been made for many centuries. Clearly, too, the measurement of the water caught for that pur-

pose offers no difficulty, but investigation soon revealed the disturbing fact that the amount of water captured by any and every rain gage varied with the nature and proximity of neighboring objects, height of the catching vessel above ground, strength of the wind, and other factors. Hence a number of investigations were required to determine the kind of apparatus to use to catch the rain, where to expose it, and how to construct it so that it automatically would make a reliable and convenient record of the time of occurrence, rate of fall and total amount of each and every rain that came.

But a device that is satisfactory for catching rain may be, and generally is, poorly adapted to the catch and measurement of snowfall. Therefore another series of investigations had to be undertaken to make the measurement of snow practicable and reasonably accurate. Furthermore, the amount of snow accumulation, especially in mountainous regions, is important, since in many cases it determines the volume of stream flow and the quantity of water available for irrigation and other uses in the valleys and plains below during the coming summer and fall, and because of its importance this accumulation must be measured, not guessed at. This problem in precipitation, too, has been solved with fair success.

Humidity is another weather factor, closely related to precipitation, that must be measured because it affects our comfort and our health, because it is important in many industries, and because a knowledge of its values at a given time over an extensive area

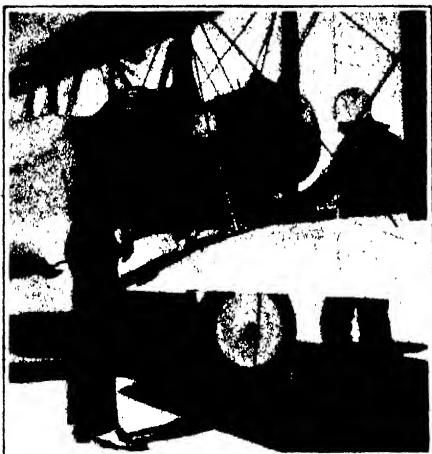
likewise is very helpful to the forecaster of the coming weather. But how shall this humidity be expressed? We have our choice between absolute humidity, that is, the weight of water vapor per unit volume, such as grains per cubic foot, or grams per cubic meter; relative humidity, or ratio of the water vapor present per unit volume to that which, at the same temperature, would produce saturation; specific humidity, or ratio of the weight of water vapor per given volume of air to the total weight of the same humid air; and vapor deficit, which likewise may be expressed in two or three different ways. We have our choice, as just stated, between these several ways of measuring and expressing humidity, but what shall the choice be? That depends on the use to be made of the data. Each has its own field of usefulness, but relative humidity, in conjunction with the current temperature, and from these in turn the dewpoint, or temperature at which the existing water vapor in the air would produce saturation, is the most convenient and useful in much the larger portion of meteorological work.

Surely, though, the measuring of hu-

midity, once we have determined what kind we want, is easy--so elementary that any high-school boy or girl taking the science course can tell you all about it. You merely have to pass a known volume of the humid air slowly over a highly drying agent which you weigh before and after the flow. This gives both the volume of the air (if the temperature and pressure have been kept constant) and the weight of the water that was in it, and there you are, at least for absolute humidity. Nice, to be sure, but that process takes more time than can be allowed an observation in the practical, current work of a weather-forecasting service. There was nothing for it then, but to go to work on the development of a speedy and reasonably accurate method of determining the current humidity of the air under any and all conditions of the weather. This was a very long and exacting investigation, or series of investigations, in which several persons took part. But here also, as well-nigh universally true, new demands for information can not be fully met by the old means, however well they fulfil the original requirements. The new demands in this case are for



CENTRAL OFFICE OF U. S. WEATHER BUREAU AT WASHINGTON, D. C.



AIRPLANE OBSERVATIONS

ARE BEING MADE AT SOME WEATHER BUREAU AIRPORT STATIONS TO TAKE THE PLACE OF KITE OBSERVATIONS. NEWARK, N. J., MAKES SUCH OBSERVATIONS BUT NOT DAILY. THIS PICTURE SHOWS THE LASHING OF THE AEROGRAPH ON WING OF PLANE FOR WEATHER HOP.

continuous, automatic and accurate records of the humidity. So far this exacting problem has been only imperfectly solved. It deserves and doubtless will receive much further investigation.

Closely associated with humidity is the phenomenon of evaporation, on which literally hundreds of papers have been written, ranging from scores that are utterly worthless to a few that are excellent and really get somewhere. To this difficult and complicated problem the U. S. Weather Bureau has contributed its full share, both in design of equipment and in actual measurements. Nevertheless, the equations thus far developed to express the rate of evaporation are either empirical or else based on assumed conditions that do not very closely obtain in nature. However, at a number of places systematic measurements of evaporation are made with standard equipment that at least will furnish valuable climatological information.

Wind vanes, used from the days of

the Romans, were readily adapted to indicating and recording the general direction of the wind, though even here a marked improvement was but recently made by giving the tail of the vane a streamline shape—an improvement suggested by certain investigations on the relation of shape to wind resistance. The measurement of wind velocity, however, was a much more difficult problem, complicated also by the fact that a portion, at least, of the measuring device has to be exposed to all sorts of weather. Through a series of investigations a practical solution of this problem was found that was adequate to the then needs, but the needs did not remain constant. Aviation has imposed upon us the necessity of solving the problem of air turbulence, and that means, as a preliminary to that solution, innumerable accurate records of wind direction, velocity and acceleration under various conditions of weather and terrain. Promising starts on this investigation have been made both in this country and abroad, but years of tedious work are still in prospect for those who would solve this important problem in all its complexity.

All these and many other investigations were essential to the adequate measuring and recording of the state and condition of the surface air. But precipitation and most of the other weather phenomena come from the free air, or are affected by it, and so the necessity was upon us to devise some means of sounding the air miles deep for its temperature, humidity, direction and velocity of movement, and any other state or condition that indicates the nature of the coming weather, or assures the aviator of what sort of atmospheric disturbance, if any, and where, he reasonably may expect aloft.

The effort to obtain this desired knowledge of the free air led at first to elaborate investigations and developments of the meteorological kite and

its equipment. Later on, the airplane, which wanted the air free from kite wires anyway, took over the equipment designed for the kite and now is regularly furnishing all the information the kite could give and more besides, and doing it more regularly, since it can go up in any wind a kite could stem, and also in wind too light to get a kite off the ground.

So much, then, in the way of mere hints, as it were, of the numerous investigations, recorded on many thousands of printed pages, incident to the design, construction and operation of the various kinds of apparatus used in obtaining reliable, serviceable and continuous records of the state of the weather.

In addition to the current use by the weather forecaster of the data obtained by means of kites, airplanes and pilot balloons—little toy-like balloons that, when properly inflated and followed by a theodolite, give the direction and velocity of the wind at various heights—they (these same data) also were employed in detailed studies of the change with height of temperature, humidity, wind direction and wind velocity as determined by time of day, season of the year, location, distribution of atmospheric pressure and state of the weather. Much knowledge of the air and its ways already has come from these studies, and it is reasonably certain that with increase of data this knowledge will become more comprehensive, more exact and more useful.

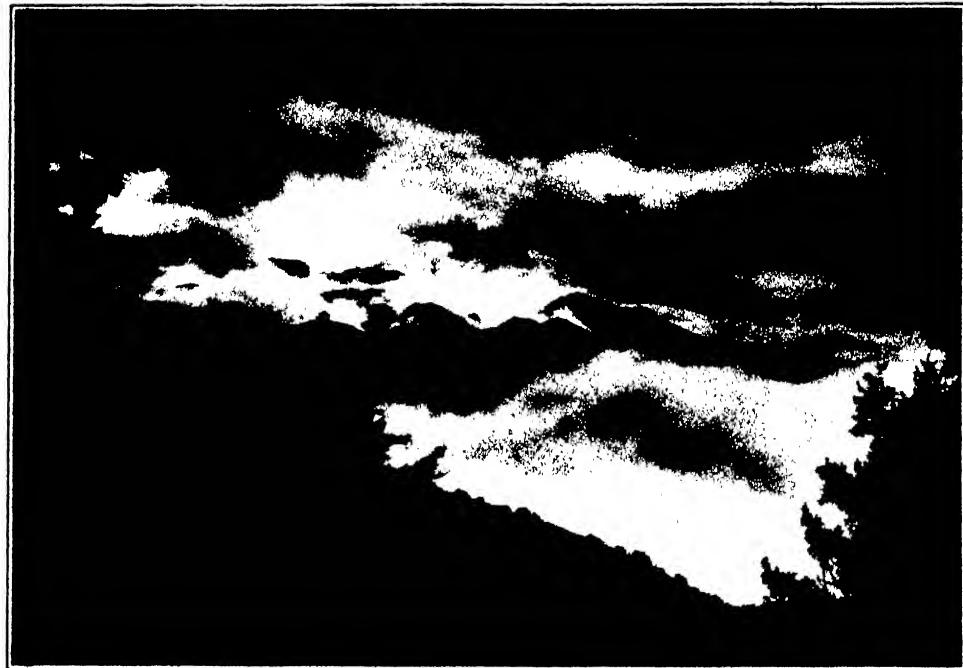
In the use of meteorological data for weather forecasting, one of the chief functions of the Weather Bureau, it is necessary of course to free them, as far as possible, from local influences so that as corrected they may represent the true expression of the general or widespread state of the atmosphere. For instance, a hill or other large object may be so situated as, in some cases, to cause air eddies at the location of the wind

vane and thereby to cause it to register wind directions quite different from those that belong to the real distribution of the weather roundabout. Such effects must be investigated and the proper corrections determined. Again the minimum temperature at and near the surface of the ground on still clear mornings may, and often does, vary by 5° to 10° F., and occasionally by even 15° to 20° in a radius of 5 to 10 miles, and that too without a difference in elevation of more than 100 to 200 feet, or perhaps less. Such large local variations, if to be allowed for at all, as in some cases they should be, require a detailed survey of the region in question. This is particularly important wherever protection from frost or freeze is necessary.

In addition to these local weather irregularities, there is one general phenomenon, namely, atmospheric pressure,



REAR END OF THE NEW FIRE-WEATHER TRUCK
SHOWING RADIO RECEIVING EQUIPMENT. THE TRUCK IS ALSO EQUIPPED WITH METEOROLOGICAL INSTRUMENTS WHICH ARE OPERATED BY A TRAINED OBSERVER. THIS TRUCK IS USED BY THE WEATHER BUREAU AND FOREST SERVICE OF THE U. S. DEPARTMENT OF AGRICULTURE.

*--F. Ellerman, photo.*

NIMBUS CLOUD ABOVE, FOG BELOW

that so differs from station to station that to render its values comparable among themselves, and of weather significance, all must be reduced to what under the existing conditions they would be if the various stations had the same level. In practise, and for reasons too tedious to explain here, it has been found that the best level for this purpose is sea-level. This, however, is a case where a correct solution of the problem, and which we know to be correct, can not be obtained. Nevertheless it is so important that a vast amount of investigation was given to it, until at last a tentative practical result was found which usually applies fairly well to our own stations. We know also the conditions under which this solution is likely to be highly erroneous, in which cases the forecaster wisely is on his guard, and, ignoring the local readings of the barometer, bases his judgment of the coming weather on other meteorological elements. A natural suggestion

in this connection, and one to which much attention has been given, is that the pressure maps be constructed for some one definite height, or for two or more definite heights, above sea-level, and actually in the air. This looks like a good and practical plan, but no easy method has been devised whereby the atmospheric pressure can be obtained at exactly a thousand feet, say, up in the air. It can be computed, but no more accurately than the reduction to an equal distance below the surface.

An interesting study, more or less analogous to that of the reduction of barometer readings to a common level, is that of the isentropic surface, the surface over which air moves with least resistance. A knowledge of the distribution of pressure over this surface might be very helpful to the forecaster, but at present that information is not available, because, for other reasons, the surface in question never stays fixed in shape so that simultaneous reduction of the pres-

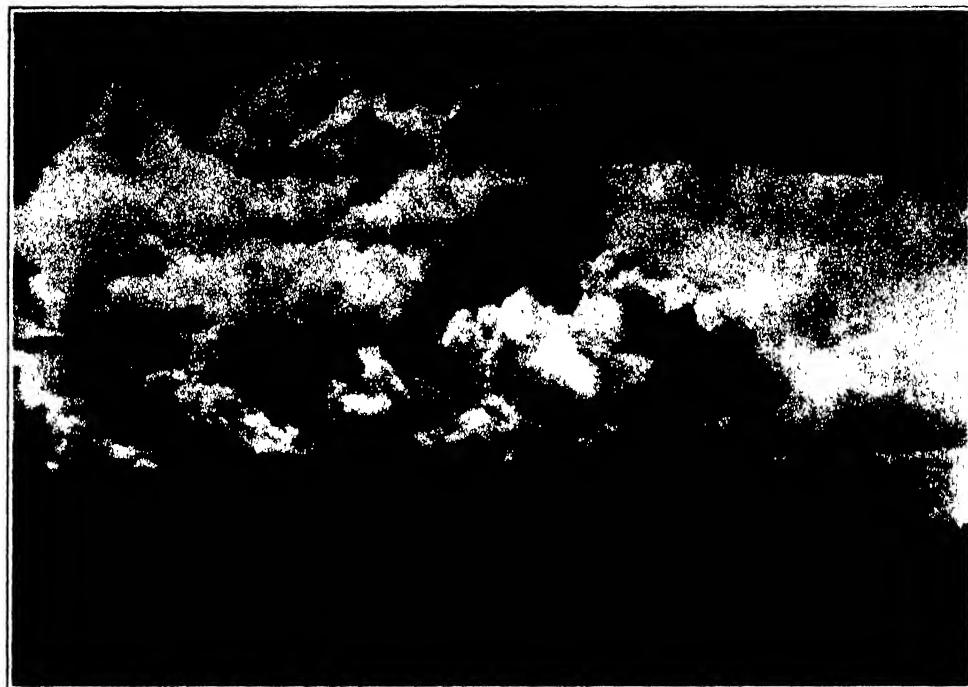
sures at various places to the same isentropic surface is impossible. Clearly, then, the problem of the reduction of the barometer in such manner as to adapt it to a map of the simultaneous weather over a large area of mountains and plains has not yet been satisfactorily solved, nor is the way to such a solution at all evident. Improvements over our present practise in dealing with this weather element no doubt will be made, for as long as it appears on the weather map (and it is too useful to drop) those who realize the seriousness of the errors in its present representation must feel a challenge to find a more reliable and helpful way of charting it.

Another subject to which much attention has been given, but of which our knowledge still is far from satisfactory, is that of fogs and clouds. We can not even classify them in a really satisfactory manner, that is, according to the methods by which they were formed, a method that would be especially helpful in making clearer their meteorological significance. At present we classify clouds according to their appearance, of which we often are in doubt, and height, which commonly is scarcely more than guessed at. Some clouds that look alike, and therefore have the same name, are formed in quite different ways and imply different sorts of coming weather. Others, on the contrary, differ widely in appearance, but little in origin and significance. In short, clouds and fogs, despite the numerous investigations that have been made of them, have given us but a fraction of the abundant meteorological information they evidently contain.

Perhaps the most fundamental of all meteorological problems is that of the reception and disposition of solar radiation. Indeed, this has led to a multitude of investigations in which the U. S. Weather Bureau has taken a creditable part, and in which it expects to continue to assist so far as practicable.

This general problem involves the frequent determination of the amount of solar radiation reaching the outer atmosphere, its selective absorption by the constituents of the atmosphere, especially oxygen (both diatomic and triatomic, or ozone) carbon dioxide and water vapor, hence also the varying amounts and distribution of these substances. It involves likewise the quantity, kind and distribution of dust throughout the atmosphere, and the kind and extent of clouds. All this and more besides concerns the incoming radiation, and the supplementary questions of how the earth disposes of this radiation are equally numerous and important, but as yet far less well understood. A large part of the incoming sunshine is lost at once by reflection and by scattering, while that which is consumed by direct absorption or otherwise must go off to space by long wave-length radiation. But this is terribly complicated by the substances of the atmosphere, particularly water vapor, carbon dioxide and ozone, and the things in the air, such as dust and cloud, and where they are, high or low. Involved here also are numerous problems of health, plant growth, air pollution, country versus city, and many others, all crying for investigation and solution.

As already stated, a major duty of the U. S. Weather Bureau is that of forecasting the coming weather for a day or two for all parts of this country. Hence several investigations have been made of the movements of cyclones and anticyclones over the United States and adjacent regions. In the main, and of necessity, these studies were for facts rather than ultimate causes, which perhaps may be discovered later. They were primarily for the important purpose of enabling the forecaster to predict the coming weather more accurately and for a longer time ahead than before had been possible. As stated, this was their prime purpose, and this, too, was their for-



CUMULO-NIMBUS CLOUD

--A. J. Weed, photo.

tunate result. Furthermore, this valuable line of investigation is still in progress with elaboration here and refinement there, with always a gain in our knowledge of the weather and its endless changes.

In addition to the general cyclone of extratropical origin and progress that so frequently passes over one or another portion of the United States, the similar, and yet widely different, storm from the tropics, the violent and destructive hurricane, must be carefully studied to the end that its coming may be predicted as accurately as possible both as to time and place. Much study has already been given to this storm, especially in the form of collecting and assembling the facts as to times of occurrence, tracks followed, strength of winds, amount of precipitation and other matters that can in any way aid the forecaster in predicting the intensity, course and general behavior of any hurricane that may be in

existence at the time. Here, too, further investigations are needed, in particular such as will aid to an understanding of the genesis of the tropical cyclone, its detailed structure and the manner of its maintenance.

Other meteorological phenomena that have been extensively investigated by the U. S. Weather Bureau are the tornado, the most violent of all atmospheric disturbances, and the thunderstorm. Each has been studied as to place of occurrence, relation of frequency to time of year and hour of day, and also in respect to their origin, maintenance and mechanism.

Not all weather forecasting is that of predicting rain or foretelling a day of calm and sunshine. A very different and difficult kind is the important one of warning of forest-fire hazard. This service is based on investigations of the dependence of the inflammability of duff and other forest material to the weather

not only of the present day but also of the several days previous. Especially are temperature, humidity and wind of importance in this connection. It also is quite helpful to know whether or not thunderstorms will occur, and whether they will be accompanied by much rain or only a little to none. Investigations of this problem have only fairly begun, but already they have abundantly proved their worth.

Another specialized investigation is that of the weather conditions likely to lead to the formation of ice on airplanes. This necessitated first of all a collection of numerous records of actual cases of the formation of ice on the planes, and then a careful analysis of these records to learn from them the exact conditions under which the ice is deposited, and the type of storm in which this phenomenon is most likely to occur. This investigation too is incomplete, but nevertheless has gone far enough for the results obtained to be of great value to the aviator who has the proper regard for the safety of plane and passenger.

Several other specialized forecasts of the weather have been requested and supplied, each requiring investigations peculiar unto itself. One of these may be cited here, owing to its great value and extensive practise, namely, fruit-frost warnings. This kind of specialized forecasting has been most extensively investigated, and is most generally practised, in connection with the citrus industry, which otherwise could not exist in this country to anything like the flourishing extent it does.

Cranberries also are systematically protected from frost injuries, but as a rule by entirely different methods from those used in the case of orchard fruits, and therefore, as well as because of the usual great difference between the temperature curves over a cranberry bog and in an orchard, predictions for this purpose had to be based on independent investigations.

Forecasting for frost protection is profitably extended to truck farming also, especially in sections where winter trucking is practical, such as the more southern portions of the country.

In addition to all the above there is quite a different sort of weather forecasting that almost every one seems to want, and which many people make for themselves, with never a failure—if you can believe what they say about it—but for all that a kind which very few well-informed meteorologists ever make, at least for publication. This is what is known as "long-range" or seasonal forecasting. It would be a matter of great importance if we could predict the weather with approximate accuracy months in advance, and innumerable attempts have been made to do this. Most of them are wholly irrational, being based on such things as onion skins, corn husks, moss on trees, squirrel stores, fox furs, etc., etc., through a list that ends only with one's patience in looking it up. But, on the other hand, some of the guides to long-range forecasting are altogether rational and worthy of serious consideration, however meager the results thus far obtained. Those rational guides are such things as depth and distribution of the snow covering; volume and temperature of ocean currents; and periodic or cyclic recurrence of much the same sort of weather. A vast amount of attention has been given to the study of weather cycles by meteorologists of different countries, and also by some capable students who are essentially astronomers or mathematicians. Thus far, however, the results of these studies have been disconcertingly poor. Cycles galore—many more than 100—have been found ranging from 744 years to 24 hours, but except for the diurnal cycle and the annual cycle all appear to be either too small in amplitude, or too uncertain, as soon as applied to the *future* to be of any forecasting value whatever.

But the end sought, successful sea-



SNOW SURVEYOR

OF THE U. S. WEATHER BUREAU, WITH HIS SAMPLING TUBE AND SCALES, OUT ON A SURVEYING TRIP. (C. S. 736.)

sonal forecasting, is most important and therefore every rational lead in that direction should, and will, be followed to its conclusion. The situation in this connection is at present discouraging, but in science one never gives over trying until the quest has been definitely proved to be hopeless.

In the meanwhile it might be justifiable in some cases to make a seasonal forecast, properly explained and qualified, based on "trends," such as a number of consecutive winters colder than the normal, or warmer, as the case may be. After several such winters, say, had occurred in succession one might assume that the next would be of the same type, but such an assumption is risky, for sooner or later the series is sure to fail. If we understood the causes of trends we would be well on the way towards using them as safe guides in seasonal

forecasting, but until we do acquire that understanding the forecaster who depends on understood causes and effects is certain to regard them with suspicion.

However, whether or not we shall ever be able reliably to predict the weather a season, or a year, ahead, at least we can assemble in convenient form the records of the past weather for as long as the records have been kept, and in many respects that is just as valuable as long-range predictions would be, because by and large the run of the weather at a particular place is much the same through any one year as through any other. This likeness does not, as every one knows, extend to details. In fact, these details may so vary as to make one year fruitful and another barren. Nevertheless, they do not so change as to convert previous deserts into enduring fertile plains, nor pleasant lands into frigid wastes—at least such changes are not wrought in a generation, nor have been, so far as we know, in the lifetime of any nation. Therefore the history of the past weather of any place, its climate, is a reliable general index to its future weather. This is why climatology has been, and is now being, so assiduously studied, and why the Weather Bureau has devoted to it so many investigations, both general and in detail. The subject is well-nigh inexhaustible. Indeed, it is no exaggeration to say that a large volume might profitably be devoted to the climatology of each and every county in all the states of the Union, and in many cases even such a single volume would have to be rather general and superficial. The climatology of one city alone in this country has been condensed (that is the proper word) into two large volumes. But what a labor! To record in adequate detail the meteorological data necessary to such a climatology of this country, and to assemble them in proper form and print the resulting volumes would keep all our idle population fully occupied for a cen-

tury; and then revisions and supplements would be necessary to keep the information up to date.

Somewhat akin to climatology are the various subjects that are grouped together under the general name of agricultural meteorology. This particular branch of meteorology has to do especially with the relation of crop yield to the weather conditions over particular periods, and is different for different regions and different crops. It also is further complicated by the fact that not one weather element, but the combination of several, enters into the final result, and additionally entangled with the effects of differences in quality of soil and lay of the land by virtue of which the weather that is good for a given crop on the one may be bad for the same sort of crop on the other. But despite the complexity of this subject investigations already have disentangled from it several helpful generalizations, and more are in sight for whoever has the courage to till this bramble field, and is well supplied with the necessary equipment therefor.

The above references to climatology and its kindred subject, agricultural meteorology, relate to surface conditions, the conditions that formerly were about all that really concerned us. Recently, however, we have taken to the free air as a medium of conveyance, and therefore have become concerned in free-air climatology, and more especially in that portion of it which has to do with the directions and speeds of the wind at various flying levels, or, specifically, from the surface of the earth to (at present) the height of six miles, at least, above sea-level.

To ascertain these facts for the whole of the United States would be an investigation of gigantic proportions, but it long has been in progress, and the results already attained are of great value and in constant use. Of course, too, any one scientifically interested in climate

and the primeval element of which it is made, that is, weather, is curious to know what brought about the great climatic changes of the geologic past. This problem is not yet certainly solved, but its study has greatly increased the extent and accuracy of our knowledge of the several things that control climate and how they in some cases supplement, and in others counteract, each other. The investigation, in this connection, of how volcanic dust in the upper atmosphere can produce its known effects on sunshine and surface temperature was especially interesting and suggestive.

Another investigation of fascinating interest was that of why the temperature of the atmosphere must decrease at the rate at which it actually does up to a certain height, generally 6 to 7 miles above sea-level, in middle latitudes, and then become constant, or nearly so, for an unknown distance beyond.

Other investigations of atmospheric and weather phenomena and their causes have been undertaken by the score and all the findings fully published.

Also, as a matter of some interest, all the hundreds of weather proverbs that have accumulated through the ages have been examined, and the rational, based on actual physical conditions, separated from the irrational and explained.

Likewise, all known schemes for inducing rainfall, or preventing it, have been critically examined, and the cause or causes of the failure of each fully explained.

But what, then, were the other weather services of the world doing while these investigations were in progress here? Much the same things, especially in relation to the conditions peculiar to their respective countries.

And what justification is there for such investigations on the part of a public institution? The improvement in that institution's service to the public which the knowledge thus acquired guarantees and makes permanent.

SCIENCE AIDS IN MOLDING BETTER LIVE STOCK

By Dr. JOHN R. MOHLER

CHIEF, BUREAU OF ANIMAL INDUSTRY, UNITED STATES DEPARTMENT OF AGRICULTURE

THE process of selection, which has played so large a part in molding the form and functions of animals into breeds of live stock, as we know them to-day, is an outgrowth of man's early attempts to domesticate animals. Those judged by the owner to be the best for his purpose were commonly kept the longest and produced the most offspring. True, many erroneous beliefs concerning heredity have existed and retarded live-stock improvement immeasurably. Yet, even the earliest live-stock owners practised selection and, judging from ancient carvings, produced some highly creditable types of domestic animals.

The passing of centuries added much practical experience but comparatively little exact scientific knowledge until in 1865 the Austrian monk, Gregor Mendel, made certain observations in plant breeding and selection. Papers reporting his observations attracted very little attention at the time, and he died in 1884 without realizing the importance of the work which he had done. Later other investigators, working independently, rediscovered the principles of breeding—now commonly known as Mendel's law—that he had formulated. This knowledge has wide application in live-stock breeding.

Through Mendel's discovery and subsequent research on the mechanism of heredity, breeders have been able to develop strains highly productive in various respects, such as milk yield in the dairy cow and egg production in poultry. Certain characteristics are

known to be dominant and in practically all cases will appear in the progeny. The white face of Hereford cattle, and the absence of horns in the Galloway, Aberdeen-Angus and Red Polled breeds are known as dominant characteristics. When an animal having one or more of these dominant traits is mated with another animal lacking these, the former's characteristics will be reproduced in the new generation. In time the desired characteristics can be established or "fixed" by mating animals both of which have the same desirable characteristics.

BREEDS AND TYPES ARE RESULTS OF SELECTIVE PROCESS

Thus live-stock breeding has established numerous breeds and types of domestic animals that excel in various specialized purposes. Other breeds ably serve a dual purpose, combining the production of meat with another commodity, such as milk, wool or eggs, in an efficient manner.

When one considers that practically all live-stock breeding in the United States is under human control and that considerably more than 100,000,000 animals are born annually, the significance of scientific studies and their practical application to this field are obvious. They involve many practical questions, some of which have been satisfactorily answered, while others are still under investigation. Particularly in those problems which relate in a broad manner to the welfare of the live-stock industry and the interests of the public,

the Bureau of Animal Industry has participated actively.

Recognizing the live-stock owners' need for basic facts about heredity and methods of live-stock improvement, the bureau prepared, about a decade ago, two publications. One, designated as "Essentials of Animal Breeding," sets forth in popular form information which previously had been relatively inaccessible. A second and more scientific discussion of the subject was prepared for the more advanced breeders and others who wish to go deeper into the study. These publications have been in extensive demand.

Simultaneously with the preparation of the publications mentioned, the Bureau of Animal Industry urged the use of pure-bred sires for grading up inferior live stock. This policy has been continuously stressed for more than a decade. It has been adopted by more than 17,000 live-stock owners, many of whom have reported extensive benefits

resulting from its use. Typical benefits include the production of higher quality and more uniform offspring, earlier maturity, greater productivity, readier salability and other assets to the stockman's business. For the information of those unfamiliar with stock-breeding operations, it may be explained that the reason for emphasis on the sire has a mathematical basis. In stock breeding the sire is a parent of vastly more progeny, on the average, than is the female animal. This explains the significance of the expression, "The sire is half the herd."

INTEREST IN LIVE-STOCK IMPROVEMENT IS WORLD-WIDE

To provide full opportunity for the public discussion of principles of stock breeding and the policy of encouraging use of pure-bred sires, the bureau has issued a considerable quantity of data in the nature of evidence. Likewise it conducted, with the assistance of other



A SLAUGHTER SCENE IN ANCIENT EGYPT,
ILLUSTRATING CREDITABLE BEEF TYPE OF CATTLE DEVELOPED BY PRIMITIVE MAN.



EXTREMES IN EQUINE STOCK.

THE SHETLAND PONY COLT AND THE PERCHERON STALLION PROVIDE A STRIKING COMPARISON.

government agencies, a world survey showing what other important live-stock countries have been doing along similar lines. The results of this survey showed that live-stock improvement is progressing the world over and is stimulated to some extent by competition in the sale of surplus breeding animals, meat and other animal products.

The free public discussion of live-stock improvement was further encouraged by the sponsoring of public mock trials at which an inferior bull, for instance, was the prisoner in "court." These trials, held in various parts of the country, have not only influenced future live-stock breeding, but have resulted in

the actual condemnation and slaughter of many inferior sires.

Besides these rather general activities the Bureau of Animal Industry has conducted numerous experiments, the results of which have materially augmented knowledge concerning animal breeding. More specifically, the work has centered largely on means of making production more economical and of improving the quality of meat and other products. In this work the bureau has cooperated extensively with other branches of the government, state agricultural experiment stations and representatives of the live-stock and meat industry. These relationships have

given breadth to the study and have brought to the attention of scientific investigators various commercial angles of the problems. For instance, in pork production certain feeds, such as peanuts and soybeans, though nutritious and otherwise desirable, have a tendency to cause a soft or oily condition of pork and lard that is objectionable to many buyers. The problem in this case was to develop rations and methods of management that would yield pork of satisfactory firmness and yet include some of the so-called softening feeds.

Another problem in recent years has been the great demand for small cuts of meat to meet the requirements of small families and small kitchens. The preference for a steak that can be cooked on a small electric grill, in a measure influences the breeding of live stock on western ranches. Similarly, the con-

sumer's demand for small legs of lamb and choice chops explains in part why about 90 per cent. of ovine stock marketed are lambs. Obviously many economic considerations, such as kind and quantity of available feed, cost of labor, differentials in market price for different grades of live stock, and other factors enter into the picture.

MOLDING ANIMALS AFFECTS INTERNAL STRUCTURE

Yet the process of molding more than 100,000,000 animals a year into the form for which the public has expressed its preference is in continual operation. Breeding and feeding are the predominant means of perfecting the desired animal types. This process of molding living animals to desired forms applies not only to the visible parts of the body but also to the internal structure, nota-



GROWING INTO THE BEEF BUSINESS.

AS A RESULT OF RESEARCH AND EXTENSION WORK, MANY FARM BOYS OF TO-DAY HAVE BECOME EXPERT IN PRODUCING EXCELLENT SPECIMENS OF LIVE STOCK.



A SCRUB-BULL TRIAL,

ILLUSTRATING A COMMUNITY'S EFFORT TO REPLACE INFERIOR BREEDING STOCK WITH MORE PROFITABLE TYPES.

bly the relation between the weight of dressed carcass and the weight of the live animal. This relationship, known to the trade as dressing percentage, varies widely, ranging from less than 50 per cent. to more than 75 per cent., according to the kind, breeding and market grade of animal.

Notwithstanding the essential functions which the vital organs perform in the growth and fattening of live stock, breeders have been highly successful in producing animals which yield a high percentage of the most valuable cuts of meat and a comparatively low percentage of organs and other so-called offal. In some instances hogs have dressed higher than 85 per cent.

The scientific study of these questions in recent years has involved refinements of methods, the application of numerous sciences, specially designed equipment, mathematical formulae and many thousands of experiment animals. Results are available in numerous publications, and the more practical phases likewise have been presented to interested persons by agricultural extension workers,

the press, radio announcements, exhibits and other means.

TYPICAL RESULTS OF CURRENT RESEARCH

The limits of this short discussion preclude the adequate presentation of recent scientific findings, but the following are typical examples:

A study to determine production efficiency in cattle and swine, based on breeding and feeding performance, carcass yield and quality of meat, resulted in the development of a mathematical system for measuring such efficiency and making comparisons.

The largest factor influencing a variation in firmness of lamb fat, with ordinary feeding methods, has been found to be the quantity of fat in the tissues rather than any variation in the character of fat itself.

Studies on firmness of fat in swine that were fed rations containing different percentages of cottonseed oil showed that the firmest fat was produced when cottonseed oil constituted 4 per cent. of

the ration. Larger percentages caused increased softness of fat.

Numerous feeding tests showed the comparative value of various rations, including those containing new feeds.

A simple method of determining, from a small sample, the clean-wool yield and density of fleece promises to aid sheepmen in the selection of breeding stock and the improvement of their flocks.

Observations on the influence of a sow's age on efficiency in pig and pork production showed that sows between two and three years old are most desirable for breeding purposes.

Experiments with poultry have resulted in the production of a flock in which yields exceeding 250 eggs per

bird annually are common, some hens laying more than 300 eggs. This rate of production, which is more than three times that of average hens in the United States, shows the possibilities of selection and the application of improved methods in poultry raising.

For much the same purpose that various industries hold annual exhibitions to acquaint the public with new styles and improvements, the live-stock industry also holds numerous shows and expositions. Here the public may see the choicest specimens of the breeders' skill—the latest models, if you prefer—of potential steaks, chops, ham, bacon, wool, horseflesh, and scores of other animal products that contribute to our well-being.

OTHERS¹

By Dr. ROSS AIKEN GORTNER

PROFESSOR OF AGRICULTURAL BIOCHEMISTRY, THE UNIVERSITY OF MINNESOTA

I FIND myself to-night in a unique position, a single asteroid selected to represent that heterogeneous group of "others" who roam more or less at random through scientific space and whose irregular orbits weave in and out among the major planetary lights of the zoologists and the botanists. In the early days of our society this asteroidal group appeared to be a major planet; or at least a part of the great central nucleus from which all specialized sciences are derived. As time went on disintegration of the central nucleus occurred. The great planets of zoology and botany were thrown off from the central orb, and their ponderous mass, moving in wide sweeping orbits, attracted much of the atmosphere which had originally surrounded the nucleus. And then—following the rumblings which accompanied the birth of the major planets, there was an explosion of the residue of the nucleus, and a swarm of "other" asteroids burst forth to fill scientific space with minor planets, sweeping in irregular paths, which in many instances cross and recross those of the major planets. It appeared as though the central orb had disappeared and that all that was left was a galaxy of stars, each moving in its own orbit "free from foreign entanglements." Emancipation had taken place! But the law of gravitation had not been overthrown! Sooner or later it was discovered that the major planets and the asteroids were still revolving around a common center, that each was mutually attracted to the other, that there was not a vacuum where the central orb had been, but that here the lines of

¹ Presidential address, delivered at the annual dinner of the American Society of Naturalists, Atlantic City, New Jersey, on December 30, 1932.

force came together and that here it was possible to integrate all the diverse interests of all the galaxy of stars in a single nucleus—Nature! This, then, is the justification for the existence of the American Society of Naturalists.

With the complacency of age, and secure in their massive dignity of might, the two major planets strove for supremacy in the galaxy, forgetting for a time that they had a common origin and that in common with the "others." But their complacency did not long exist. The intertwining orbits of the major planets and of the asteroids occasionally provoked collisions. Sometimes an asteroid was captured and continued to revolve as a satellite around a major planet, but, more often than not, the collision had a disastrous effect upon the mass of the major planet, for by the force of the impact a portion of the major planet was detached and a new asteroid was born, sometimes to remain as a satellite, but sometimes to roam on its own irregular path through new and unoccupied regions of scientific space. Thus from year to year more and more asteroids were added to the galaxy, and the traffic problems of the major planets became more and more difficult.

In 1931, in a typical American fashion, a commission was appointed to study this traffic problem, and the report of that commission provides for a series of stop-go signals at points where the orbits intersect, with right of way given one year to the zoologists, one year to the botanists, and the third year to one of the asteroids—an "other"! Let us hope that this will provide a paradox—fewer collisions but more contacts!

The programs of the American Society of Naturalists are by tradition devoted

to some phase of the broad problems of evolution. As a representative of the "others" I do not intend to deviate from that tradition. But evolution is a broad word and may be interpreted from many standpoints. It may relate to mutations, or to progressive changes in genera or species, to changes in structural form, to changes in mental capacity, to changes in social organization, to changes in the career of an individual, or of the development from the individual to the family, to the clan, to the tribe, to the nation, to a specific civilization, yes, it may be the development of civilizations themselves; the relation of our civilization to the "other" civilizations which preceded us and to the "others" which are to follow. It is this phase of evolution which I wish to consider this evening, taking as my thesis that progress in material civilization is largely, if not wholly, determined by progress in the fields of applied science.

Yesterday, to-day and to-morrow! We are here! From whence came we? And whither are we going? And why?

It has been stated² that the earliest date in human history which can be fixed with certainty is July 19, 4241 B. C. The calendar year of ancient Egypt consisted of 365 days, divided into twelve months of thirty days each, with five additional intercalary days. The twelve months were divided into three seasons, the inundation, the sowing and the harvest. The first day of the first year was fixed because of the simultaneous occurrence of two extraordinary events, the beginning of the rise of the waters of the Nile and the simultaneous appearance of both the sun and the star Sothis (Sirius) on the horizon at the moment of sunrise. This astronomical coincidence is known as the heliacal rising of Sothis, and the phenomenon, known as the Sothic cycle, reoccurs every 1,460 solar years or every 1,461 Egyptian civil years.

In the course of Egyptian history this

² A. Moret and G. Davy, "From Tribe to Empire," p. 134. Alfred Knopf, N. Y., 1926.

heliacal rising of Sirius occurred in 4241, 2781, and 1321 B. C., and 140 A. D., but the Egyptian calendar, based on the Sothic cycle, had been in use prior to the IV Dynasty, so that the introduction of the calendar must have antedated 2781 B. C. and accordingly could not have been initiated later than 4241 B. C. The calculations of modern astronomers show that at dawn on July 19, 4241 B. C., in the latitude of Memphis, this heliacal rising could have been observed, and accordingly this is the *latest* date at which the calendar of ancient Egypt could have been initiated. It may have been 1,460 or some multiple of 1,460 years earlier!

My purpose in calling attention to this date is to emphasize the fact that, as early as 4241 B. C., the science of astronomy was highly developed in the early Egyptian civilization.

Let us imagine that the group of scientific men present here to-night could, with all their modern and varied scientific training, by some magic be transported backward through time to Memphis at dawn on July 19, 4241 B. C., and there, facing the eastern horizon, are viewing the rising of the sun. How many would observe that an unparalleled and unrecorded astronomical phenomenon was taking place? Probably the heliacal rising would pass unobserved! And yet the priests of ancient Egypt were sufficiently versed in the phenomena of the heavens to recognize and commemorate this unusual event! The more that the ancient records reveal, the more respect one has for the knowledge possessed by the civilizations of the past.

On the plains of Arizona, near Casa Grande, stands a prehistoric ruin. Built in the form of a double hollow square, one rectangle within another, three stories high, of adobe mud, with walls four feet thick, it probably formed the citadel of an extensive and populous city. The eastern wall of this ruin is pierced by a hole, perhaps two inches in diameter, passing entirely through the

four-foot wall of adobe. The wall of the inner room is pierced with a corresponding hole, and at sunrise on March 7 the rays of the sun pass through the hole in the outer wall, stream across the corridor of the outer room, pass through the hole in the four-foot inner wall of adobe, stream across the inner room, and strike the center of a rude cross on the opposite wall. This phenomenon occurs again at sunrise on October 7. Was it a calendar marking the beginning and end of the summer season? The sowing and the reaping? We can only believe it was this, and we can only wonder how a primitive race, in the stone age, could, without modern engineering instruments, construct these two holes, forming essentially a tube some two inches in diameter and perhaps forty feet long, inclined at the exact angle to permit the unobstructed passage of the rays of the rising sun throughout its entire length.

The prehistoric civilization in the Casa Grande valley left no written records, but the country for miles around bears evidence of their culture and industry. One may drive in an automobile for miles on the bottom of their irrigation ditches, in some of which two cars may still drive abreast of each other with walls still rising high on each side. When these ditches are excavated to the original puddled adobe bottoms, and when the transits of the modern irrigation engineer are sighted down them, it is found that they wind across the plain with an almost exactly uniform rate of fall, mile after mile. Dug by stone-age people, with stone implements, and the earth removed in baskets, they are works which challenge the precision of the irrigation engineer of to-day; and the waters of the new Gila River project are, in part, flowing through the cleaned-out irrigation ditches of prehistoric man.

These peoples cremated their dead, and the area where the ashes were deposited is rich with millions of tiny beads, beautifully worked from shell or agate or

turquoise. Many of these beads do not exceed two millimeters in diameter and are pierced by a hole so fine that only a human hair can be passed. The fineness of the opening challenges the best skill of the best lapidaries of to-day. How did stone age man accomplish this with stone age tools? That question still awaits solution.

We have only to contemplate the extensive prehistoric irrigation systems of our own Southwest and of the valleys of the Tigris and Euphrates, the achievements of the builders of the pyramids, and of the temples of Baalek, to recognize that the ancient civilizations had progressed a long way in the sciences as applied to engineering problems. But the sciences of those ancient civilizations were largely limited to astronomy, which was probably associated with their religious practices, and to the field of applied physics as related to mechanics. These, with a crude understanding of metallography, provided the basis of their material culture. When, in the course of time, these ancient civilizations were swept aside, a new philosophy dominated scientific thought. Speculation was sufficient, experimentation was unnecessary, and through much of the Greek and Roman eras and down through the middle ages, the speculative writings of the philosophers held scientific progress in abeyance. The dreams of the dreamers were accepted as authoritative.

Modern science and modern civilizations differ from those of the ancients in that all the natural sciences are emphasized and in that experimentally demonstrated facts are demanded. Extensive and intensive research is systematically prosecuted in all directions, and new scientific facts are hardly announced by their discoverer before some utilitarianly-minded person incorporates them into the structure which modern man is building for his aggrandizement, comfort, or convenience.

Which, perhaps, brings us to the question, "What is science?" The uninitiated and uninformed often define it as "the organized body of facts relating to natural phenomena," a definition which implies a degree of finality which the true scientific man is unwilling to assume.

I am willing to grant that there *appears* to be a large measure of finality in what we accept as fundamental scientific principles, but as a scientific man I should not at all be surprised if even some of these "scientific principles" should ultimately be shown to be only crude approximations, or be wholly replaced by new and more fundamental conceptions. The demonstrator of a new fact is often the executioner of an old theory, and a theory is of value only in so long as it is supported by the facts.

Unfortunately the layman does not always recognize the truth of this statement, and often assumes that the theories of the scientific man, because they are stated as theories, are without a factual basis. We have witnessed in the past few years the attempts of those ignorant of scientific facts to legislate against scientific theories. Perhaps no more fitting reply can be made to them than was made by President Coffman, of the University of Minnesota, when, speaking before the Legislature of the State of Minnesota in opposition to an "anti-evolution" bill, he turned the tables upon his opponents and pointed out that even in the field of religion there has been an evolutionary progression. President Coffman³ said:

The spirit of America will wither and decay when the correctness of scientific theories is decided by legislation or by the counting of heads. If that method had been followed in the past as is proposed to-day, we should be meeting to-night clothed in the skins of beasts we had killed by bows and arrows. Squatted around a campfire in a cave we should be trying to decide

³ L. D. Coffman, "The Teaching of Evolution," *School and Society*, 31: 754-758. June 7, 1930.

whether to burn or behead some member of our tribe who said that the god of the harvest was greater than the god of the hunt.

By a long, upward trail, by trial and error, in sending to the stake or the rack those who were eager to know the truth and to explain it, the human race has come to cherish learning and support the labor of scholars. It no longer drags learners before courts and throws men who are seekers of truth into dungeons. It has done wiser and better things. It has founded schools and colleges and universities. In these it has gathered the scholars and thinkers who can find better ways than our fathers knew and teach them to our children. It is to the scientists or the expert in any line that we turn for an answer in scientific matters. We know that he must be free to find the facts as best he may and equally free to seek a theory or hypothesis that explains them. If there is error in his deductions, there is only one way that it can be shown and that is by his own ceaseless and unimpeded search and the labors of his fellow scientists. Mistakes may be made, but unrestricted research is the only means by which they can be corrected. If we are to have better science, we can not get it by legislative decree but by giving teachers and investigators the utmost freedom. If those who know most can not discover and correct error, we who know less can not help by majority votes or minority clamor.

Only a scientific man fully appreciates how quickly a theory is swept into the discard when new scientific facts incompatible with that theory are discovered. There hangs upon the wall of my office a motto clipped many years ago from some advertising literature. It reads: "It's the fellow that doesn't know any better that does the thing that can't be done. You see, the blamed fool doesn't know it can't be done, so he goes ahead and does it." That motto has encouraged me more than once to attempt to proceed along paths which were apparently barred by some particular theory, and to attempt to differentiate more sharply between scientific theory and scientific fact.

The chemistry which most of us studied in our undergraduate days was vastly different from the chemistry of to-day. Then the atom was a round, hard ball, the ultimate unit of matter, in-

divisible, non-transmutable. How we smiled at the ignorance of the alchemists who believed in the impossible—the transmutation of the elements! To-day all this is changed. The atom was yesterday a solar system, mostly empty space with a tiny but heavy nucleus of closely packed protons and electrons surrounded by a cloud of electrons moving in fixed orbits with a speed approximating that of light. To-day we are not sure that either electrons or protons exist as definite entities, they may be only waves of energy. Matter as such may be only a localized manifestation of some special form of energy. Even the fundamental concepts of the conservation of matter and of energy have undergone radical changes within the last two decades, and we now believe that matter and energy are interconvertible. The transmutation of the elements in the scheme of nature is a proven and universally accepted fact; and the dream of the alchemist of a forced transmutation has been accomplished in the laboratory. Those of us who have lived through these revolutionary discoveries may well wonder what new conceptions the future will bring forth.

The tremendous increase in knowledge in the physical sciences during the last hundred years has made possible the material civilization in which we live to-day. The material aspects of our grandfather's civilization were closer to those of the civilizations of ancient Egypt and Assyria than are the material attributes of our civilization—a hundred years later—to those of our grandfathers.

Contrast, if you will, 1832 and 1932; soft soap made by the housewife from the hardwood ashes of the fireplace and the fat dripping from the kitchen, and to-day the equipment of a single modern manufacturer of more than eighty kettles each holding 50,000 pounds of fat; then candles for lighting, now the gas-filled bulbs; then largely homespun dyed with

natural pigments, now rayons, silks and fine fabrics in all colors of the rainbow are accepted as a matter of course; then wooden buildings were put together largely with wooden pegs because of the expense of hand-wrought nails, now the steel frames of our skyscrapers are welded into a single piece of metal; then surgery without anesthetics, medicine without antiseptics or the modern synthetic drugs, transportation by horseback or stage-coach, but why go on? The average farm home of to-day is luxury itself as compared with the middle-class home of only a hundred years ago.

Our present rapid progress in material conveniences is due to the fact that we have accepted the scientific man as being capable of doing the impossible! In 1844 the world was electrified when the message, "What hath God wrought?" was tapped out over a wire stretched between Baltimore and Washington, and in 1927 New York flashed a *spoken* message *without wires* across the ocean to London!

It was my good fortune to be present at the international air races at Mineola, Long Island, on October 27, 1910. A prize of \$10,000 had been posted for that pilot who would fly his plane fifteen miles to the west, circle the Statue of Liberty, and return to the field without landing. Plane after plane disappeared in the distance, but none returned! The last plane was wheeled out, and it carried the American flag. It took off, disappeared and later it reappeared again high in the western sky and coasted to a landing on the field. The prize had been won for America, and the burst of enthusiasm from the crowd is one I will long remember. And the sequel came only seventeen years later when Lindbergh flew alone from New York to Paris!

An editorial⁴ in a recent scientific journal beautifully expresses the casual

⁴ *Ind. Eng. Chem.*, 22: 205 (1930).

acceptance of the achievements of the scientific man. It reads as follows:

Some indication of what we have come to expect as a result of the past achievements of science is to be found in the attention given in the daily press to what would have been considered as impossibility a brief decade ago.

A representative of Admiral Byrd required an immediate decision in New York. The admiral's representative, seated at a telephone, communicated with the operators of the radio room of the *New York Times* and dictated the messages he wished to transmit to the admiral in Little America, emphasizing the urgency of an immediate acknowledgment. Imagine his surprise to be told laconically to hold the phone, and overhear the operator explain that the messages must be put through for an immediate answer—"he is holding the wire." While the wire was held these messages went through to the Antarctic, nine thousand miles away, and in less than five minutes the operator reported "Lofgren (Admiral Byrd's secretary) says hold on a minute or two. Byrd is replying."

In twenty minutes from the time of the first telephone conversation, Admiral Byrd had made his reply to his representative and he had hung up. Of course the conditions were favorable at the time and everything possible was done to facilitate the sending and the receipt of the messages. Nevertheless, to us it is one of the many modern miracles.

Now where do you suppose such an important bit of news finds a place these days? On the fifteenth page, section 1, of a metropolitan daily. Such accomplishments are no longer front-page news; the public has come to expect so much of science.

And the civilizations of the future—will they follow the trends of the civilization of to-day? Will the complexities of life increase in geometric ratio with the passing of each decade? Will the wheels of our industrial life turn ever faster and faster, until a hundred or even five-hundred years from now an individual will, in a ten-year period, meet as many problems, see as many accomplishments, achieve as many results, as we meet, see or achieve in our lifetime, just as we in a ten-year period to-day live a lifetime of our grandfather's day? The answer to this question can be given almost with finality. Probably not! The wheels of industry *must* inevitably slow down, not necessarily for the reason that man can not mentally or phys-

ically stand up under the increased tension of an ever-increasing complexity of life, but rather because our modern materialistic and industrial civilization has so changed our natural environment as to limit the possibilities available to future generations.

The great civilization of ancient Egypt arose in the valley of the Nile, a region almost devoid of mineral resources. Early in its history Egypt asserted hegemony over the Sinai peninsula, for there copper could be obtained. Metallurgy probably had its origin in this region, and there we can still see the mining galleries, the crucibles which were used for smelting the ore and the heaps of slag which resulted. The carved inscriptions of Egyptian monarchs, boasting of their wealth and power, remain cut in the living rock, but the sound of the pick and the sledge is forever stilled, and only the nomad roams over the desert waste, for the copper ore, placed there by natural forces uncontrollable by man, is gone.

The history of ancient Egypt is replete with wars, not of conquest, but wars waged against those who threatened the domination of Egypt over this copper-bearing area. The Egyptian state acquired the copper mines on Sinai about 3300 B. C., and this natural resource transformed the material and industrial life of ancient Egypt. Her supremacy in the ancient world remained, essentially unchallenged, for approximately 2,000 years, until the copper ore was exhausted about 1500 B. C. Then she fell before the onslaught of the Hyksôs, the Hittites and the "Peoples of the North," hordes which swept out of the north with weapons of bronze and iron, mounted on horses or riding in terrible war chariots drawn by horses. Better weaponed and more mobile than the Egyptians, who were not acquainted with iron and who knew only the ass, the culture of ancient Egypt was overwhelmed by the barbarian. Was it only a coincidence that the state of ancient

Egypt came to an end at approximately the same time that her resources in the form of metal-bearing ores were exhausted! The stone age gave way to the bronze age. The bronze age fell with the advent of iron and steel. The man with the club could not cope with the man with the sling. The slinger fell before the archer. Gunpowder again changed the maps of the world. Inventive genius and available natural resources even to-day determine whether a nation shall survive or perish.

The records of early man are few and indistinct. Perhaps a half a million years of progress were necessary before he reached the stage where a written language was developed. The written records which were left by these early civilizations, and which seem so old and strange to us, are only yesterday's news items in the history of mankind.

Malthus in 1798 called attention to the fact that populations increase with time not in an arithmetical but rather in a geometrical ratio, and it is now rather generally accepted that most generalized biological responses, such as growth rates, form sigmoid curves; each successive increment being slowly added at first, then faster and faster until, when maturity is approached, the rate gradually slows down and eventually becomes stationary. In so far as the possibilities of applied science are concerned, we are probably close to the bottom of the steep portion of a sigmoid curve, and *a priori* we may assume that applied science will accomplish greater and greater achievements with greater and greater frequency as the years unfold. Such an assumption, however, presupposes a *normal* curve, just as a normal growth rate assumes health, adequate nutrition and the other factors of an optimum environment. No one will question the health of the infant, "Applied Science," but careful thinkers have already raised disturbing questions in regard to its future nutrition. In the

last hundred years this lusty infant has increased its food consumption perhaps a thousand fold, and, unfortunately for mankind, already the shelves in some of nature's cupboards show signs of exhaustion of specific food supplies.

All that applied science has as yet done for man is to adapt to man's use certain of the natural resources of man's environment, and in many instances these natural resources, on which our modern industrial civilization is absolutely dependent, show probabilities of exhaustion in the almost immediate future. Jaeger⁵ has summed up in a terse paragraph the problem that faces us.

Techniques and industry in their present aspect would be obliterated if the natural resources of supply of such metals as iron, copper, tin, lead, zinc, etc., should suddenly become completely exhausted. Dynamo and steam engine would in that case irrevocably disappear, just as the monsters of earlier geological epochs, the ichthyosaurus and the megatherium, vanished as soon as conditions became incompatible to their existence. Industry and traffic in their present form would become quite impossible. And the same is true, if the stores of coal and oil were no longer at our disposal. Attention has repeatedly been drawn to the fact that the danger of such a catastrophe is not very remote if we continue to squander our capital of raw materials in the reckless way that has been pursued in the past and indeed is even now being followed.

And the stores of copper, antimony, tin, lead, zinc, chromium, manganese, nickel, iron, oil and coal stored in that portion of the lithosphere which is accessible to man will probably be exhausted in less than one thousand years if used at their present rates of consumption, and the rate of consumption in some instances is doubling with the passage of each decade! Read⁶ notes that, "There is not a single mineral sub-

⁵ F. M. Jaeger, "The Present and Future State of Our Natural Resources," *Science*, 69: 437-445, 1929.

⁶ T. T. Read, "Our Mineral Civilization," Williams and Wilkins Company, Baltimore, (1932).

stance of which the quantity used in the past century is less than the total of all the centuries that preceded."

Through untold millions of years these natural resources have been accumulating here and there in isolated areas near the surface of the lithosphere. Through tens of thousands of years man has been slowly differentiating from the other forms of the animal kingdom. Suddenly —within the last hundred years—he has had placed in his hands the tools of science, and with them he has already wrested from the earth from 10 to 50 per cent. of the natural resources which are there available, has enjoyed them for a moment, and then, either destroying them or casting them aside in a form useless to coming generations, he has turned with an ever-increasing vigor to the task of further depleting the potential supply.

We send our fellow men into the bowels of the earth to dig for iron. Other fellow men labor in the heat of the furnace, where enormous amounts of energy from coal and oil are expended, to produce the steel. By a further expenditure of man power and energy the steel is fabricated into battleships and weapons of war, and, in a few years, when these become obsolete, they, serving as targets for newer battleships, are sunk forever in the oceans. In the oceans and lakes, and along the highways and byways of the countryside, the frames of America's old automobiles are rapidly rusted away. Thousands upon thousands of tons of metal are cast aside after man has played with it for a brief moment, and, unfortunately, cast aside in a form which makes it unavailable to generations yet unborn.

In spite of the fact that the world's resources of tin are exceedingly limited, we still demand tinfoil around candy bars and packages of cigarettes, and the world's available sulfur supply is being rapidly exhausted in the demand for cellulose products which have a silken

sheen. Such illustrations could be extended almost indefinitely. I have called it a "modern civilization." Viewing our wastage of natural resources, I sometimes wonder if we are civilized.

It has been estimated that the iron of Germany will be exhausted in forty to fifty years, that of Scandinavia and of the United States in less than one hundred years, that of Russia in less than one hundred and fifty years, and that all the iron mines of the world will be mined out at the present rate of mining in less than two hundred and fifty years. The copper, zinc, lead and tin resources of the world will be exhausted long before the iron is gone!

Taylor⁷ has recently studied the sulfur problem. The world resources of elemental sulfur approximate 120,000,000 metric tons, of which the United States has the largest single supply of approximately 40,000,000 metric tons. At its present rate of use the American supply will be exhausted in fifteen years! And the world supply, including 450,000,000 metric tons as available from pyrites, will last the world at the present rate of usage not to exceed one hundred and fifty years!

Binz⁸ has considered these problems in an illuminating fashion. He points out that the energy resources of the world will far outlast the metallic resources, but that even the energy resources are extremely limited. These resources represent the radiant energy sent out from the sun through bygone geologic ages and fixed by plants through the agency of photosynthesis. Stored in the earth in the form of coal and oil they constitute the energy source for our modern industrial civilizations, and the energy reserve for the civilizations which are to follow. At the present rate of consumption the coal of England

⁷ A. M. Taylor, "Economic Position of Sulfur," *Ind. Eng. Chem.*, 24: 1118, 1932.

⁸ A. Binz, "Chemie, Technik, und Weltgeschichte," *Z. angew. Chemie*, 40: 449-455, 1927.

will last about fifty years, that of France less than three hundred years, that of Belgium less than eight hundred years, that of Germany less than a thousand years and that of the United States, including our vast lignite deposits, less than fifteen hundred years.

The chances of man finding another energy source which will replace that which we now secure from coal and oil is exceedingly remote. Transeau⁹ has rightly pointed out that if all the corn grown in America, including grain, leaves and stalks, were converted 100 per cent. into alcohol, the energy so made available would not equal that necessary to operate the automobiles which we operate on gasoline to-day. And the corn plant is one of the most efficient plants in the fixation of solar energy!

Energy derived from available water power of our inland streams would be utterly inadequate in amount. Solar mirrors, tide machines, and the like can be dismissed as an improbable ultimate solution of the energy problem, for iron and other metals necessary for the construction of such equipment will no longer be available in quantity when the need arises. If all the iron which we utilize to-day were to be utilized solely for the construction of mirror frames and solar engines, and if each year's output of iron were added to such construction, and the solar mirrors and engines were placed in a tropical cloudless region, we should still find that our present energy demand had not been met.

Binz suggests that the temperate zone where our industrial civilization is now most highly developed may, when our energy supplies are exhausted, become uninhabitable. That man will again be limited to the tropics and the subtropics

⁹ E. N. Transeau, "The Accumulation of Energy by Plants," *Ohio Jour. Sci.*, 26: 1-10, 1926.

where snow does not fall, and then, if that be the case, in this, their more favorable environment, the brown, black and yellow races will come into their own.

Perhaps the picture has been over-drawn. Perhaps the colors are too lurid. Perhaps other virgin supplies, unknown to man to-day, exist in unexploited regions. Perhaps the date of exhaustion may be moved another thousand years into the future. A thousand or five thousand years? It is but a moment in the history of mankind!

Has the applied science of the white man raised up a Frankenstein which will ultimately destroy him, or will the scientific men of the future solve these problems which appear to us insoluble? Will future civilizations look back upon the industrial civilization of the twentieth century not as an age of progress but rather as an age of despoilation, as to-day we look back upon the Tartars and the Vandals and the Huns who destroyed the civilization of Greece and Rome? Will the wheel of time turn man backward to a more primitive and isolated existence, with the horse and the wooden sailboat again his only means of transportation?

These are questions which can not be answered now. Only the historians of future generations can answer them, but we can assert, with a high degree of finality, that the civilizations of the future will be vastly different from the civilization of to-day; and that if the upward progress of mankind is not to slacken or to fail altogether, the scientific men of the future must solve infinitely more difficult problems than those which face the scientific men of to-day.

Yesterday, to-day and to-morrow! We are here! We know somewhat from whence we came, we know not whither we are going.

LIQUIDATION AND REHABILITATION OF THE CONSUMER AND SMALL BUSINESS

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THE tremendous economic and social waste involved annually in the failure of firms and individuals is illustrated by the recording in the fiscal year ending June 30, 1931, of more than 60,000 bankruptcies alone, involving in excess of one billion dollars of liabilities. The increase in obligations is about 9 per cent. annually of the average for the period 1911 to 1931.

Similarly, the annual increase in the number of bankruptcies in the northern district of Illinois is 5 per cent. of the average for the period 1916 to 1931, while the average increase in liabilities is 8 per cent. In the last four years, the New York district has accounted on an average for about 38 per cent. of the total bankruptcies of the United States and about 10 per cent. of the total liabilities, while the northern district of Illinois has approximated 33 per cent. of the total number and 5 per cent. of the total liability.

Using the average volume for the years 1923 to 1925 inclusive as the base, or 100 per cent., in each case, Chicago bank clearings fell from about 113 per cent. in 1929 to 88 per cent. in 1930 and 59 per cent. in 1931. In the same period, commercial failure liabilities of the Seventh Federal Reserve District, centered in Chicago, rose from about 96 per cent. in 1929 to 145 per cent. in 1930 and 178 per cent. in 1931. At the same time, liabilities in closed bankruptcy cases in the northern district of Illinois dropped from 195 per cent. in 1929 to 162 per cent. in 1930, and then rose to 175 per cent. in 1931. However, for the period 1880-1925, Carl Snyder¹ calculated that

¹ "Business Cycles and Business Measurements," pp. 182-183.

the relation of liabilities to bank clearings outside New York City declined from about \$4,000 of liabilities per \$1,000,000 of bank clearings to an average of about \$1,000 liabilities to \$1,000,000 of bank clearings. In the same period the number of firms failing increased at about the same rate as population and the number of firms in business.

It is important to consider failure not as a depression phenomenon, but as a chronic disorder in our economic system.

The problem affects the stability of the debtor family, the welfare of the creditor, and the functioning of the economic process.

In seeking insight into the problems and factors of insolvency and rehabilitation, analysis was made in the Chicago area of liquidation by bankruptcy, assignment and receivership, of stabilization by creditor and cooperative management, of methods used by going concerns to meet current problems and of processes and agencies of recuperation. Methods employed include statistical and case analysis. Interviews were held with the failed individuals and representatives of corporate firms, and contacts were established with creditors and competitors, and in some instances with customers and neighbors. Surveys were made of neighborhood conditions, including vacancies and unemployment, while going concerns in the same areas and fields of business were studied as controls. Only bankruptcy cases are considered in this report.²

² Though collection of bankruptcy data was in collaboration with the United States Department of Commerce, represented by Mr. Victor Sad, analyses and inferences are exclusively the responsibility of the author.

BUSINESS FAILURES

Analysis of factors influential in the failure of business concerns indicates that about one half of the individual proprietors failed because of discernible errors in management, and that an additional one fourth succumbed to environmental conditions over which they had no control. One tenth of the proprietors

TABLE I
PRINCIPAL FACTORS IN FAILURE OF INDIVIDUAL PROPRIETORS IN RETAIL BUSINESS

Factors	Number of cases	Per cent. of cases
Management:	199	50.13
Capital:	26	6.54
Inadequate organization	12	3.02
Mortgage	2	.50
Fixtures and equipment	12	3.02
Overhead	48	12.09
Credit extension	18	4.53
Expansion	15	3.78
Location	22	5.54
Experience	28	7.05
Negligence	11	2.77
Endorsing notes	6	1.51
General incompetence	25	6.30
Environmental conditions:	109	27.45
Competition:	70	17.63
Price	15	3.78
Chain	37	9.32
Other	18	4.53
Neighborhood changes: 39		9.82
Highway obstruction	2	.50
Migration	2	.50
Closed factories	12	3.02
Closed banks	4	1.01
Inventory deflation	10	2.52
Burglary or fire	9	2.27
Family affairs:	39	9.82
Medical expenses	13	3.28
Illness of bankrupt	9	2.27
Extravagance	9	2.27
Dependents	8	2.02
Personal characteristics:	8	2.02
Speculation:	29	7.80
Real estate	24	6.04
Stock	5	1.28
Miscellaneous	13	3.28
Total	397	100.00
		100.00

suffered reverses due largely to family affairs, such as illness, while one fourteenth sacrificed their regular business to the whims of speculation. In Table I, the principal factors are indicated in their relative importance.

The largest item of mismanagement is the failure to control overhead expenses. Business rent was the most frequent difficulty in this category. Proprietors signed lease contracts in anticipation of large business volumes which never materialized. Landlords, impelled by the apparent advantage to them of the contract or by a joint understanding as to rent levels in particular locations, were reluctant to yield.

Among environmental factors chain store competition was dominant. The chain store in most instances has been characterized by lower costs (including rentals), reduced consumer prices of many commodities, and more modern business facilities. However, it is not apparent that the chain store as an institution is eliminating the best of the individual proprietors. It would appear that most of the failures occurred to marginal firms, parasitic in nature, which could remain in business only so long as not challenged by pressure of economic forces or of modern business methods.

Real estate venture greatly outweighed security speculation as a factor in the failure of proprietors.

Under management, three problems of capital have been differentiated. In twelve instances proprietors attempted to establish their concerns with inadequate reserve; a few proprietors even brought to the new business an indebtedness incurred in a previous failure. In two cases the mortgage burden was a millstone precluding all possibility of floating the business. Capital problems of fixtures and equipment include primarily over-investment, but in a few cases inadequate facilities for operation.

Location is a site value with respect to consumer patronage as contrasted with neighborhood conditions, an environmental factor. In twenty-two cases the inauspicious location of the store made success improbable, and in almost all such cases no effort was made to evaluate the location before establishing the business.

A distinction is made between experience, which refers to practice in the particular field, and general incompetence, which infers lack of ability and judgment in the conduct of business. The latter category, of course, has an arbitrary standard of judgment. Only such cases were entered in this group as indicated recurrent mismanagement in various phases of business. For instance, if a proprietor extended credit beyond safety, withdrew from the business for personal use funds considerably in excess of a warranted proportion, and, in addition, was uncivil to customers, he was forthright relegated to general incompetence.

In several neighborhoods of the city of Chicago, distinct migrations are apparent—racial, national or economic. A proprietor whose business over a period of years has been attuned to a particular clientele may find himself confronting adjustment to a new group of customers. Such changes are frequently difficult not alone because of personal habit but, even more significant, because of group customs and animosities.

Inventory deflation is a frequent experience in all business, but becomes a formidable factor with the appearance of new inventions or sudden changes in style. Decreased demand for musical instruments with the advent of radios is an illustration of the first group, changes in the length of women's skirts, of the second.

By extravagance is meant uncontrolled expenditure in excess of income without regard for budget relationships.

An expenditure for residence rent aggregating 30 per cent. of the annual income was considered excessive. On the other hand, emergency medical expenses which normally would not be included in the budget did not relegate a family to this category. Such an emergency expenditure was classified as a separate factor, "medical expenses."

In eight instances support of relatives who previously had been independent added a burden which the business could not maintain.

Another category of arbitrary judgment is designated "personal characteristics." In this group are several illiterate persons whose chances of success even in the neighborhoods of lowest standards of intelligence seemed exceedingly small. In a few instances, repugnant personality seemed to be a large factor in failure as gauged by the interviewer's estimate and by inquiry in the neighborhood in which the person operated.

In the miscellaneous group as included primarily cases in which a strong suspicion of irregular practices or fraud was present, without evidence that could be accepted by a court. Case studies divulged no other factors which would seem to account for the bankruptcy of this group.

Contributory causes, secondary to principal factors in importance, are recorded in Table II. Again, the predominance of errors in management, particularly with reference to capital and overhead control, are impressive. Since several contributory factors are frequently associated with one principal factor, the total number of causes involved in Table II is in excess of the totals of Table I.

There is little evidence of correlation among primary and secondary factors. For instance, chain-store competition is a principal factor in the failure of 13 of the total of 41 grocery stores. Asso-

TABLE II
CONTRIBUTORY FACTORS IN FAILURE OF INDIVIDUAL PROPRIETORS IN RETAIL BUSINESS

Factors	Number of cases	Per cent. of cases
Management:		
Capital:		
General	61	9.26
Mortgage	25	3.79
Fixtures and equipment	10	1.52
Loan and finance company loans	4	.61
Overhead	85	12.90
Credit extension	12	1.82
Expansion	5	.76
Location	25	3.79
Experience	46	6.98
Negligence	20	3.04
Endorsing notes	2	.30
General incompetence	44	6.68
Environmental conditions:		
Competition:		
Price	14	2.12
Chain	35	5.31
Other	46	6.98
Neighborhood changes	49	7.43
Inventory deflation	9	1.37
Burglary or fire	5	.76
Family affairs:		
Medical expenses	25	3.79
Illness of bankrupt	14	2.12
Extravagance	6	.91
Number of dependents	26	3.95
Personal characteristics		
Speculation:		
Real estate	14	2.12
Stock	4	.61
Creditor pressure	6	.91
Miscellaneous	41	6.22
Total	659	100.00

ciated as auxiliary factors are the following: neighborhood conditions, 4; lack of experience, 4; capital problems, 2; general incompetence, 2. Similarly, with inexperience, which occurs 4 times, are associated lack of capital, 2; chain store competition, 2; and one each of the following: overhead, poor location and illiteracy.

In the case of grocers, again, inexperience occurs as an auxiliary factor 9 times, associated with the following:

chain store competition, 4; and one each of the following: credit extension, capital problems, neglect of business and excessive overhead. Capital problems, appearing 8 times as a subsidiary factor, is associated twice with chain store competition, twice with inexperience, and once each with negligence, real estate speculation and excessive overhead, as principal factors.

In the drug and restaurant fields, there was no concentration of causes. Chain store competition appears most frequently in the case of the drug field, but only in 5 of a total of 28 cases. With restaurants, inexperience of operators was the most frequent in occurrence, but again in only 5 of a total of 29 cases.

Similar scatterings of factors occur in men's wear, women's wear, dry goods and other clothing.

CONSUMER FAILURES

Of 411 personal failures, 72, or 17½ per cent., though employees for at least the previous year, had once been business proprietors and had sought bankruptcy largely because of the pressure of obligations incurred in this earlier status. Though family incomes, expenditures and assets of this group are comparable to the consumer group in general, liabilities, both in volume and character, require separate consideration. It is not surprising to find about 31 per cent. of the salespersons represented in this special group, but to discover that 9 per cent. of the laborers were involved is a fact of social significance. As disclosed later, large groups of proprietors failing in business have recourse to some form of labor which many of them hoped would be only a transitory occupation.

Unwarranted excess of expenditures over income, "living beyond income," is the principal factor in the failure of 17½ per cent. of all personal bankrupts. It is effective similarly in the case of 22 per cent. of the salespersons and 14 per cent. of the laborers. This factor was

referred to as "extravagance" in business failure categories. In establishing norms as bases for judgment, incomes and expenditures were considered both in the absolute and in relation to each other. Emergency expenditures, such as expenses of illness, did not relegate a family to this category. A contractual expenditure, such as residence rent, was considered not alone relative to the income of the twelve months preceding failure but, in addition, to the income of the second year previous in order to correct for possible income decreases.

Sudden decreases in salary, sufficiently large relatively as to prevent immediate readjustment, entered as a separate category in 2 per cent. of the cases.

Speculation plays relatively a large part in the bankruptcy of several occupational groups. The interest in real estate is noticeable. By "home speculation" is meant the assumption of interest and amortization obligations in the purchase of a residence far beyond the possibilities of income, considering other liabilities as well.

A summary of principal factors in personal bankruptcy is provided in Table III.

Included in the miscellaneous category are gambling, betting, automobile accidents and liabilities, frequent intoxication, bank failures, insolvency of bankrupt's debtors, and similar items.

Of 21 salespersons who failed largely because of extravagant living, excessive retail credit was associated in 10 cases, and instalment purchases in 8, and salary decreases in 8 others. Subsidiary causes associated with these 21 cases numbered 48.

In 9 cases in which real estate speculation was a principal factor, only once does stock speculation appear as a contributory factor. However, in 10 cases with stock speculation as a chief factor, real estate speculation occurs 3 times as auxiliary.

TABLE III
PRINCIPAL FACTORS IN PERSONAL BANKRUPTCIES

Factors	Number of cases	Per cent. main group	Per cent. subgroups
Debts from former business	72	17.52	17.52
Living beyond income	72	17.52	17.52
Speculation:	81	19.71	
Real estate	41		9.98
Stock market	16		3.89
Home	24		5.84
Employment:	48	11.67	
Part-time ..	19		4.62
Unemployment	29		7.05
Illness:	45	10.95	
Bankrupt ..	17		4.14
Family	22		5.35
Death	6		1.46
Dependents:	11	2.68	
Own	5		1.22
Relatives	6		1.46
Signing notes	23	5.60	5.60
Family difficulties	15	3.65	
Divorce	10		2.43
Excessive rent	0		
Other	5		1.22
Decrease in salary	10	2.43	2.43
Miscellaneous	34	8.27	8.27
Total	411	100.00	100.00

FAMILY INCOME

While incomes of the families of individual proprietors show a concentration centered at about \$1,300, the interval from \$1,200 to \$1,399 includes only approximately 10 per cent. of those cases for which data were available. Within the range \$1,000 to \$1,599 is found slightly more than one fourth of the total. However, there are five other intervals, each of which exceeds 6 per cent. of the total; 3 of these are close to 8 per cent. Dividing the number of items into fourths, the first quartile value is \$1,284, the median, \$2,004 and the third quartile, \$2,763.

Similarly, although family incomes of

personal bankrupts indicate a concentration at approximately \$2,000, the dispersion records many large frequencies in other income classes. There are forty-three cases in each of the intervals, \$1,800 to \$1,999, and \$2,000 to \$2,199.

The minimum and maximum frequency of the five class intervals between \$800 and \$1,799 are twenty-one and thirty-two. Twenty-one incomes range between \$6,050 and \$20,000, seven of these \$10,000 or higher. The quartile values are as follows: first, \$1,324; median, \$1,949; third, \$2,617.

Comparing the two dispersions, the following facts are pertinent: the median incomes differ by fifty-five dollars in favor of the business bankrupts. The differences between the first and second quartiles, and between the second and third, respectively, for the business group are \$720 and \$759, and for the personal group, \$625 and \$668, indicating a fair degree of regularity. Consequently, there is little difference in the

income classes represented by the business and consumer groups, the former withdrawing compensation from the firms of which they are proprietors, the latter, as employees, receiving salaries and wages.

EXPENDITURES

Although the income of the business group is not high as a whole, the percentages which personal withdrawals are of the total sales of the particular business are both an excessive drain upon the business and relatively higher than the norm found in going concerns of the same type of business. The same is true of rentals paid for business accommodation. In Table IV are recorded for various business fields, central values of ratios of rent to annual net sales.

The following summary records for solvent concerns the range of ratios of rent to net sales for six types of business. The stores used as controls and recording these rents in the period for which failures were studied, though handicapped by depression conditions, showed evidence of ability to continue as "going concerns."

TABLE IV
PERCENTAGE BUSINESS RENT OF TOTAL SALES

Type of business	All known cases			Excluding "no rent" cases		
	Number of firms	Median	Mean	Number of cases	Median	Mean
Drugs	35	16.5	25.0	35	16.5	25.0
Restaurants	33	13.8	16.0	33	13.8	16.0
Men's clothing	38	19.4	25.5	36	20.0	27.0
Women's clothing	68	13.5	19.4	68	13.5	19.4
Total clothing	135	15.3	21.8	133	15.6	22.1
Food	99	9.5	13.0	99	9.5	13.0
Hardware	18	15.0	22.5	18	15.0	22.5
Furniture	22	19.0	26.7	22	19.0	26.7
Total retail	542	14.3	22.6	532	14.6	23.0
Manufacturing	137	5.8	9.5	136	5.9	9.6
Wholesaling	35	4.1	6.5	31	4.7	7.3
Miscellaneous services*	109	10.0	23.3	89	15.5	28.7
All bankrupt	823	11.9	19.3	788	12.6	20.0

* Professional, Miscellaneous Proprietor, Contractor and Realtor.

Kind of business	Range, rent as per cent. of sales
Drug	4.7- 8.8
Grocery	6.0-10.0
Men's clothing	9.0-14.0
Women's clothing	6.0-10.0
Women's specialty shops	10.0-15.0
Hardware	10.0-12.0

Nineteen per cent. of the personal bankrupts expended for residence rent from 30 per cent. to 34.9 per cent. of their total incomes. The median ratio was approximately 31 per cent., the first quartile, 21 per cent., and the third quartile, 39 per cent.

Approximately 53 per cent. of the personal bankrupts spent 30 per cent. or more of their incomes for residence

rent; the proportion of cases with this rent ratio was slightly exceeded by the business group. If we assume from 20 to 25 per cent. of the income as an adequate allowance for rental, both the business proprietor and employee bankrupts have been excessive in this branch of their expenditures.

Expenditures for illness were analyzed for 427 of the personal bankrupts. Twenty-three per cent. of this group had no medical or dental expenditures in the year preceding bankruptcy. While the average expenditure for those having illness in the family was \$395 in the twelve-month period, and while 23 families had expenditures of \$1,000 or more, the arithmetic average does not give a valid picture of the problem due to the weight of a small number of large values.

Selecting a concentrated group with medical expenses of less than \$1,000 annually and with income of less than \$4,800, it is found that more than 45 per cent. of the families had spent less than \$200 for medical care, and almost 53 per cent. had expenditures less than \$250.

Again, while the mean ratio of medical expenses to total income is 20.4 per cent., the modal ratio, representing approximately 23 per cent. of the total number of families, is only 2.5 per cent. Of the 54 families with medical expenses 25 per cent. or more of their total annual income, 44 had incomes of less than \$2,600. Of the 13 families with medical expenditures of 50 per cent. or more of income, 10 had incomes of less than \$2,200.

Therefore, while the bankruptcy group as a whole was not seriously affected by medical expenses, a significant proportion had its solvency jeopardized by illness.

ASSETS AND LIABILITIES

Until disposed of by sale, available asset evaluations are the estimates of the bankrupts and of the court. Usually

the bankrupt's appraisement is optimistic, based upon his desire to make a good showing as well as upon his recollection of original cost and his estimate of replacement value. On the other hand, the court estimate usually is affected by the expectation of forced sale. The bankrupt's evaluation is the first available since it is a part of his bankruptcy petition. The income received from disposal of the bankrupt's equities is referred to as realized assets. Due to the time period involved, a complete statement of realized assets is frequently not available until the closing of the case, a maximum of two years subsequent to the filing of the petition.

Similarly, liabilities are scheduled by the bankrupt as an estimate of his indebtedness to others. They are probably fairly close to the total indebtedness, though there are occasionally discrepancies. Since he is endeavoring to free himself of all obligations, the debtor is very likely to record all obligations.

Approximately 51 per cent. of the retailers scheduled assets less than 20 per cent. of their liabilities and almost 48 per cent. of the total business group scheduled similarly limited proportions. Nine per cent. of the total business group scheduled assets in excess of liabilities. Three items—accounts receivable, real estate equities, and stock in trade—account for the excess of assets in approximately 77 per cent. of the cases. All these items are doubtlessly overestimated. There will be large shrinkage on the accounts receivable, and considerable depreciation when the stock is liquidated at forced sale. In addition, real estate values are usually based upon the 1924 to 1929 markets rather than upon present deflated values. Fixtures bring very small prices at forced sale.

Indicative of the proportions of cases and liability amounts represented by various business fields is the summary in Table V. The importance of the real

TABLE V
TOTAL BUSINESS LIABILITIES—INDIVIDUAL PROPRIETORS

Business group	Number of cases	Per cent. of total cases	Amount in dollars	Mean in dollars	Per cent. of total amount
Total retail	498	75.34	5,749,919	11,546	32.73
Total wholesale	22	3.33	378,911	17,223	2.16
Total manufacturing	46	6.96	1,920,073	41,741	10.93
Agriculture	4	.61	21,540	5,385	.12
Miscellaneous trades and services	53	8.02	1,055,821	19,921	6.01
Real estate	38	5.74	8,440,240	222,112	48.06
Total—all business	661	100.00	17,566,504	26,576	100.00

estate business in volume of obligations is apparent.

A similar picture is given in Table VI for certain retail trades. As indicated, restaurants are not included in the food

of the total amount was recorded for the real estate field. Of the \$1,444,266 secured liabilities in the retail trade, 23 per cent. is recorded for the food industry, 19 per cent. for clothing.

TABLE VI
TOTAL BUSINESS LIABILITIES—RETAIL PROPRIETORS

Business group	Number of cases	Per cent. of total cases	Amount in dollars	Mean in dollars	Per cent. of total amount
Groceries	42	8.43	558,489	13,297	9.71
Total food	91	18.27	883,180	9,705	15.36
Restaurants	32	6.43	495,493	15,484	8.62
Drugs	28	5.62	439,527	15,697	7.64
Total men's clothing	35	7.03	272,102	7,774	4.73
Total women's clothing	72	14.46	753,253	10,462	13.10
Total clothing	134	26.91	1,362,814	10,170	23.70
Total retail	498	100.00	5,749,919	11,546	100.00

group; the latter, in addition to groceries, includes meats, bakeries, delicatessens and other shops not serving meals.

Of \$2,388,101 owed by retailers to wholesalers, 31 per cent. was the proportion of the total obligation owed by clothing firms. Food concerns accounted for 11 per cent. Clothing outlets represented 28 per cent. of the number indebted to wholesalers, and food merchants, 18 per cent. Restaurants and drug stores were relatively most obligated to landlords.

A total of \$9,693,668 of the liability was supported by collateral; two thirds

Comparisons of scheduled assets and liabilities for personal bankrupts leave small hope of settlement of creditor claims. About 70 per cent. of the cases had less than one fifth of their liabilities covered by assets. Of 15 estimating assets in excess of liabilities, 11 scheduled real estate equities.

In Table VII liabilities of personal bankrupts are recorded by occupational classifications. The special group of 80 personal bankrupts with previous business indebtedness has been excluded from this table. Individual persons and retailers were the two leading creditor groups.

TABLE VII
TOTAL LIABILITIES OF PERSONAL BANKRUPTS BY OCCUPATION

Occupation	Number of cases	Per cent. of total cases	Amount in dollars	Per cent. of total amount	Mean in dollars
Public service	1	.30	111,911	2.41	111,911
Recreation	2	.59	9,076	.20	4,538
Professional	17	5.01	327,619	7.04	19,271
Domestic	20	5.90	738,773	15.88	36,938
Salespersons	65	19.17	884,832	19.02	13,612
Demonstrator	1	.30	1,401	.03	1,401
Sales agent	1	.30	10,962	.24	10,962
Clerk	41	12.09	158,827	3.41	3,873
Manager	22	6.49	711,015	15.29	32,318
Laborer	148	43.66	1,364,412	29.34	9,219
Other	21	6.19	332,267	7.14	15,822
Total	339	100.00	4,651,095	100.00	13,720

The proportion of scheduled assets realized at forced sale was computed for the 115 business bankruptcy cases closed by the date of this analysis. The remaining cases were still before the court for completion. The tremendous shrinkage in value between the original estimate and the receipt from sale is apparent from the fact that less than 15 per cent. of value was realized from assets of 47 per cent. of the individual proprietors and 34 per cent. of the corporations and partnerships. Eighty per cent. of the cases ultimately showed a loss to general creditors of 90 per cent. or more.

REHABILITATION

With businesses liquidated, their assets confiscated and with neither homes nor credit, bankrupts usually leave the neighborhood of their previous activities and residence. If employed, there is some possibility of the family remaining intact. Frequently the family is divided, the wife and children going to relatives and the husband remaining in the community, attempting to locate employment. Of letters sent to the home addresses of all bankrupts three to seven months after petitioning, approximately 10 per cent. were answered, and

about 55 per cent. of the letters were returned with addresses changed and unknown.

Of 42 personal bankrupts for whom this information was available, 30 had found employment. Twenty-nine of the 97 business proprietors were still unemployed. Only 22 of the former business men and 15 of the personal bankrupts were employed full time. Of those employed, the largest group obtained jobs through application from place to place, or through recommendations of friends.

One half of the business group with earned income reported income less than 60 per cent. of their respective pre-bankruptcy earnings. One half of the personal group received less than 90 per cent. of previous earnings. Ten of the former business proprietors and nine of the personal bankrupts reported earned incomes equal to or in excess of previous earnings. However, the apparent favorableness of present income is largely a relative matter. Of those recorded as receiving currently 180 per cent. or more of previous income, the range of incomes was from \$200 to \$1,250, indicating the very inadequate earnings of their earlier status.

Outside aid came principally from

relatives, approximately 63 per cent. of the cases receiving outside assistance recording this source. About 18 per cent. of the families were assisted by relief organizations and 10 per cent. by friends. The remaining 8 per cent. of the cases recorded miscellaneous sources.

PROPOSALS

It is important to recognize failures not as depression phenomena, primarily an emergency or a cyclical event, but as a continuing fundamental problem of our economic structure.

An agency is needed to propose standards and tests of ability and experience requisite to control of business enterprises in various fields. The various trade associations might logically initiate such a movement, if only in defense of their creditor members. However, the total problem transcends the interests and abilities of any trade group. It is a task for a group varying in technical and specialized knowledge.

There is urgent need for the development of cooperative management counselling by business fields, a device by which small merchants would employ in association an expert in business control with power to budget and to alter policies and processes.

Significant studies are needed to provide standards for (a) selection of store locations, and (b) establishing of the

most efficient sizes of particular business units.

Creditors, in their blind desire for increase in volume of business, have oversold merchant debtors, bringing insolvency upon those they sought as customers. Both the action of trade associations and the adequate use of more efficient credit agencies is desirable.

Stimulation of consumption by pressure selling has helped to disorganize orderly purchasing. There is fundamental need of recognition that most of our population receives very low income and that purchase by the consumer of current luxuries can be accomplished only by a shift in expenditures for necessities or by deferment indefinitely of payment. Either outlet is detrimental to individual and social welfare. Careful analysis of consumer "needs" rather than potential competitive sales is overdue.

Much education is required in budgeting of business and family expenditures.

Importance of illness as a factor in failure suggests the immediate extension of social preventive and curative medicine.

Disorganization of families and of communities requires a change of emphasis from amelioration of emergency conditions to planned prevention and rehabilitation. This is a function of social organization.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

MINERAL RESOURCES, AN INTERNATIONAL RESPONSIBILITY

By Professor RICHARD M. FIELD

DEPARTMENT OF GEOLOGY, PRINCETON UNIVERSITY

HUMAN beings are absolutely dependent upon their environment, but their environment has become so complex that they are likely to forget the fundamental physical and biological factors which are still essential to existence. Man's social evolution has taken at least two hundred thousand years, and during most of this time his primary concern has been the same as that of all other animals—the need of food, a suitable physical environment and the desire to have children. While even to-day these still remain the primary wants of human beings, during the last few thousand years man, through the accumulated experience of his ancestors, has developed and expanded the possibility of his environment until it has become the infinitely complex sum of those so-called necessities for his health and his happiness which he considers to be an important part of modern civilization. To-day the lives of millions of men and women do not depend so much upon their individual efforts in acquiring the raw products from the breast of mother nature, as upon a common social scheme by which the raw natural resources of the earth are refined and made useful to all. In this modern age of invention, mass production and faulty methods of distribution, we are apt to forget that the physical character of modern civilization is controlled by the diversity, the quality, the quantity, and the geographic distribution of raw natural resources.

All natural resources may be grouped under two principal divisions, agricultural and mineral. Mineral resources have become increasingly important during the social evolution of man, culminating in what is often referred to as the machine age. Obviously, there would be no modern machines or the products of these machines, if there were no metals. It is a peculiar attribute of all metals that they are extracted from minerals. The economically important minerals have been concentrated by nature in the form of ores. When these ores have been exhausted they can not be reproduced by man. Minerals, unlike the essential elements of food and clothing, can not be reproduced as can raw agricultural products. The mineral fuels of the world also constitute an energy reserve which has been similarly created by natural agencies through millions of years, and which man may consume but he can not reproduce. The ultimate supply of mineral resources naturally depends upon the discovery of new supplies and the rate of consumption. Unquestionably man has not discovered all the mineral resources, including coal and oil. The recently improved methods of prospecting and refining have added greatly to the world's reserve of metals and fuels. Man is, therefore, concerned with the quality and amount of mineral reserves, but the problem of conservation is not as prominent as it was a few years ago. At the present time the geographic dis-

tribution of coal, oil and rich concentrates of metallic minerals is far more important, from an international point of view.

Exclusive of the precious metals, platinum, gold and silver, there are twelve important metals which occur in the complex form of minerals. According to statistics accumulated by the United States Government "28 minerals constitute more than 70 per cent. of the gross value of the mineral raw materials of commerce." At the present time two thirds of the essential mineral resources of the world are controlled by the United States and the British Empire, that is, by the English-speaking peoples. In other words, the English-speaking peoples have, by one means or another, gradually acquired the absolute, or partial, control of the major proportion of mineral wealth. This mineral wealth supplies twelve important metals, which are first, the base metals, iron, copper, aluminum, lead, zinc, tin and nickel; and the alloy metals, or hardeners, antimony, chromium, manganese and tungsten.

Besides the above-mentioned metals, there are the important non-metallic minerals, such as coal, oil, nitrates, phosphates, potash, and a number of others essential to industrial and agricultural prosperity.

In normal business times the United States has all the minerals which she needs within her own sovereign territory, with the exception of the alloy metals and nitrates.¹ It is perhaps news

¹ The United States produces over a million and a quarter tons of synthetic sodium nitrate a year. The total United States nitrogen production is well over 600,000 tons, which is far in excess of either our peace or war-time requirements (Professor J. Enrique Zanetti, Department of Chemistry, Columbia University). This is an illustration of how the former necessity for Chile saltpeter is being overcome by inventive ingenuity and leads to the statement "It should be abundantly evident that public affairs are being more and more divorced from

to some that, in spite of the fact that the United States produces nearly 71 per cent. of the world's petroleum, in good business times she consumes over this amount.² The only net excess of raw mineral commodities which the United States has for export are coal, phosphates and sulfur. Although the United States is exceedingly rich in mineral resources, she consumes more than any other nation by reason of the number and energy of her people, whose wealth depends upon foreign, as well as domestic, trade.

Since the world war, Germany has an inadequate supply of metallic minerals to meet her domestic demands. She has a very limited supply of copper, iron and lead ores within her sovereign territory, and is entirely dependent upon other countries for all the other metals. Germany does, however, have more coal and potash than she needs for her own consumption.

France, at the present time, is in reality only a little better off than Germany. She has more aluminum potash and iron than she needs, but, like Germany, she now imports her petroleum. France also, normally, imports part of her coal.

England has an excess of coal and an adequate supply of iron, some lead and tin, but has to import everything else. If, however, we consider England as the center of the British Empire, then the

the classical rules of international diplomacy, and are becoming increasingly susceptible to conditions imposed not only by accident of material distribution but also by excellence of scientific and technical achievement" (Professor Hugh S. Taylor, Department of Chemistry, Princeton University). It is hardly to be expected, however, that even eventually the ingenuity of the chemist will entirely overcome the economic problems arising from the unequal geographic distribution of mineral resources (R. M. Field).

² While several countries have succeeded in substituting powdered coal and petroleum distilled from bituminous shale and coal, none of these products can be produced as cheaply as natural petroleum (R. M. Field).

picture is quite different, for the British Empire has an excess of all the essential minerals, with the exception of antimony, potash and mercury.

The economic power of Great Britain, therefore, really depends entirely upon the solidity of the British Empire, and her ability to derive industrial minerals from sources which she either politically or commercially controls. Thus, while she surpasses the United States in the control of excess mineral resources, this control is not exercised within her sovereign territory, but is exceedingly far-flung and is held only with increasing difficulty.

The Japanese situation is the present outstanding problem in mineral resources. Japan has barely enough copper and zinc for domestic consumption. She has an inadequate supply of iron, chromite, manganese, coal and petroleum, and is *entirely* dependent on other nations for all other mineral supplies. Hence Japan is tremendously interested in assuring herself of the continuing right to exploit the mineral resources of neighboring territory, because she will thus become much more independent of foreign nations than she is at the present time.

Belgium has no adequate supply of minerals for her needs, except coal and copper, and has to import all important minerals.

Italy is probably in at least as difficult a position as Japan, as she has no control over petroleum and coal, and is but little better off as to iron and lead. It should be noted that both Italy and Japan now rank as first-class powers, and are struggling to maintain that position in spite of serious deficiencies in their mineral resources. They are in an even worse position than England would be if she were divorced from the British Empire.

Spain presents an entirely different problem since, with the exception of certain ferro-alloys, coking coal and perhaps

petroleum, she has deposits of most of the important mineral resources within her sovereign territory, and has an excess of copper, iron, lead, manganese and mercury for export. Here we have a clear case of a nation that is playing a passive rôle in the development of her natural resources, and, therefore, may eventually become a source of trouble to herself and a cause of discord in the international affairs of Western Europe. "The political boundaries of the nations, originally drawn on considerations dominantly agricultural in origin, have now no natural relation to the national reserves of mineral wealth."³ This is a very serious situation, which has exerted and will continue to exert a powerful effect on commerce and world peace. The developments of peace have moreover fundamentally changed military requirements for war. Because of the improvement and complexity of machinery used in war, mineral resources are now a vital factor in both attack and defense. The fact that the Allies did sell essential minerals to Germany for the manufacture of lethal weapons will serve to illustrate still another difficulty which arises from the unequal geographic distribution of mineral resources. Tungsten is an essential element in the manufacture of high-grade tool steel. The principal source of tungsten is the mineral w-o-l-f-r-a-m-i-t-e, obtained mainly from South Burma. The Burma mines are controlled by the British. When the world war broke out, the Germans had laid in two years' supply of wolframite. When Germany had used up her imported reserve of wolframite she procured m-o-l-y-b-d-e-n-u-m as a substitute for tungsten from a neutral nation, Norway. This move was partly countered by the British purchase of this Norwegian output. Germany then substituted the next best alloy metal, nickel, in quantities ten times greater than Central Europe

³ Sir Thomas Holland.

could produce; so she imported her nickel through the neutral Scandinavian countries, and they, being neutral, were able to obtain nickel from Canada—the world's main source of rich nickel ores. In prohibiting the use of tungsten in Germany, England dealt her a serious blow; had England, however, been able to keep Germany from acquiring an adequate supply of nickel, the Allies would undoubtedly have won an earlier victory.⁸

The conclusion to be drawn from the above digest is that the mineral resources of the world are too few and irregularly distributed for each nation

to become self-sufficient. Some nations have more than their share of the great mineral reserves; some lack adequate reserves; and even the particularly blessed lack some important minerals. This has been known by geologists for many years.

No matter what other factors may affect international affairs, there never can be established a reasonable degree of friendship among nations, with the consequent reestablishment of world prosperity, until the geographic distribution of mineral resources is seriously considered from an international point of view.

EARTHQUAKES—WHAT ARE THEY?

By the Reverend JAMES B. MACELWANE, S.J.

PROFESSOR OF GEOPHYSICS, ST. LOUIS UNIVERSITY

ROUND about this earth of ours there run certain belts in which earthquakes occur more often than in other parts of the world. Why should this be the case? We read from time to time of destructive earthquakes in Japan. But many lesser shocks occur there of which we never hear. In fact, there is an earthquake, large or small, somewhere in Japan practically every day. Similarly, the Kurile Islands, the Aleutian Islands, Alaska and the Queen Charlotte Islands are subject to frequent earth shocks. Continuing around the Pacific circle, we meet with many earthquakes in California, Mexico, Central America, Venezuela, Colombia, Ecuador, Bolivia, Peru and Chili. And on the other side of the Pacific Ocean, the earthquake belt continues from Japan southward through Formosa and the Philippine Deep to New Zealand. Another somewhat less striking earthquake zone runs from Mexico and the Antilles through the northern Mediterranean countries and Asia Minor into the Pamirs, Turkestan, Assam and the In-

dian Ocean. In other parts of the earth, destructive earthquakes also occur, but as more or less isolated phenomena. Examples in this country are the Mississippi Valley earthquakes of 1811 and of the following year, and the Charleston earthquake of 1886.

Now why should destructive earthquakes occur more frequently in such a zone or belt as is the border of the Pacific Ocean? What is an earthquake? Centuries ago, many people, and even scientific men, thought that earthquakes were caused by explosions down in the earth; and there have not been wanting men in our own time who held this view. Others, like Alexander von Humboldt, thought that earthquakes were connected with volcanoes; that the earth is a ball of molten lava covered by a thin shell of rock and that the volcanoes were a sort of safety valve. As long as the volcanoes are active, they said, the pressure within the molten lava of the earth is held down, but when the volcanoes cease their activity, thus closing the safety valves, so to speak, the increasing

pressure eventually causes a fracture in the earth's crust. Another theory supposed that the lava occupied passage-ways in a more or less solid portion of the earth underneath the crust and that the movement of lava within these passages caused such pressure as to burst their walls, thus causing an earthquake.

Quite a different point of view was taken by those who held the theory that earthquakes occurred within the uppermost crust of the earth. This crust was supposed to be honeycombed with vast caves. Even the whole mountain chain of the Alps was thought to be an immense arch built up over a cavern. When the arch would break, thus allowing the overlying rocks to drop somewhat, we would have an earthquake. In many cases, those who held this theory believed that the entire roof would collapse and that earthquakes are generally due to the impact of the falling mass of rocks on the floor of the cavern.

But it has been shown, since the discovery of the passage of earthquake waves through the earth and their registration by means of seismographs, that the outer portion of the earth down to a depth of at least five elevenths of the earth's radius is not only solid, but, with the exception of the outer layers, is more than twice as rigid as steel in the laboratory. It has also been shown that volcanoes are a purely surface phenomenon; that they have no connection with each other, even when they are but a few miles apart. Hence it is clear that earthquakes connected with volcanoes must be of very local character, if they are to be caused by the movement of lava. This is found to be actually the case. It is also clear that some other cause must operate in producing earthquakes, since destructive earthquakes often occur very far from volcanoes. In fact, some regions where there are frequent earthquakes have no volcanoes at all.

In the California earthquake of 1906,

there occurred a fracture of the earth's crust which could be followed at the surface for a distance of more than 150 miles, extending from the Gualala River Valley on the northern coast of California southeastward through Tomales Bay and outside the Golden Gate to the old mission of San Juan Bautista. The rocks on the east side of this fracture moved southeastward relatively to those on the west side, so that every road, fence or other structure which had been built across the line of fracture was offset by varying amounts up to 21 feet. A study of this earthquake led scientific men to the conclusion that the mechanism of the earthquake was an elastic rebound. It was thought that the rocks in the portion of the earth's crust west of the fracture had been dragged northward until the ultimate strength of the rocks was reached along this zone of weakness. When the fracture occurred, the rocks, like bent springs, sprang back to an unstrained position. But this did not occur in one continuous throw, but in a series of jerks, each of which set up elastic vibrations in the rocks. These vibrations traveled out in all directions and constituted the earthquake proper. The zone of weakness in which the California earthquake occurred is a valley known as the San Andreas rift. It is usually quite straight and ignores entirely the physiography of the region, passing indifferently over lowlands and mountains and extending more than 300 miles beyond the end of the fracture of 1906 until it is lost in the Colorado desert east of San Bernardino. The entire floor of the valley has been broken up by earthquakes occurring through the ages into small blocks and ridges and even into rock flour.

The San Andreas rift is only one of the many features which parallel the Pacific Coast in California. There are other lesser rifts on which earthquakes have occurred. Similar to these rifts in some respects are the ocean deeps, along

the walls of which occur some of the world's most violent earthquakes.

Why do these features parallel the Pacific shore? And why are earthquakes associated with them? Both seem to be connected in some way with the process of mountain-building, for many of the features in this circum-Pacific belt are geologically recent. Many have thought that mountain-building in general and the processes going on around the Pacific in particular are due to a shortening of the earth's crust caused by gradual cooling of the interior and the consequent shrinkage, but this is not evident. While the earth is surely losing heat by radiation into space, it is being heated by physical and chemical processes connected with radioactivity at such a rate that, unless the radioactive minerals are confined to the uppermost ten miles or so of the earth's crust, the earth must be getting hotter instead of cooler, because the amount of heat generated must exceed that which is conducted to the surface and radiated away.

Another suggested cause of earthquakes is isostatic compensation. If we take a column of rock extending downward from the top of a mountain chain to a given level within the earth's crust and compare it with another column extending to the same level under a plain, the mountain column will be considerably longer than the other and consequently will contain more rock. Hence it should weigh more, unless the rocks of which it is composed are lighter than those under the plain, but geodesists tell us that the two columns weigh the same. Hence the rocks under the plain must be the heavier of the two. But even if this is the case, we should expect the conditions to change; for rain and weather are continually removing rocks from the tops of the mountains and distributing the materials of which they are composed over the plain. Nevertheless,

according to the geodesists, the columns continue to weigh the same. Hence we must conclude that compensation in some form must be taking place. There must be an inflow of rock into the mountain column and an outflow from the plain column. But the cold flow of a portion of a mass of rock must place enormous strain on the surrounding portions. When the stress reaches the ultimate strength of the rocks, there must be fracture and a relief of strain, thus causing an earthquake.

It has recently been found that earthquakes occur at considerable depth in the earth. Hence they can not be caused by purely surface strains. There are a few earthquakes which seem to have occurred at depths up to 300 miles. This is far below the depth of compensation of the geodesists. It is also below the zone of fracture of the geologists, and far down in what they call the zone of flow. Can an earthquake be generated by a simple regional flow? We do not know, but it would seem that sudden release of strain is necessary to cause the vibrations which we call an earthquake. It may be that a strain is produced and gradually grows in such a way as to produce planes of shear such as occur when a column is compressed lengthwise. These planes of maximum shear usually form an angle of about forty-five degrees with the direction of the force. Recent investigation into the failure of steel indicates that under certain conditions it will retain its full strength up to the moment of failure when the steel becomes as plastic as mud along the planes of maximum shear. The two portions of the column then glide over each other on the plastic zone until the strain is relieved, whereupon the steel within the zone becomes hard and rigid as before. It may be that a process somewhat similar to this may take place deep down in the earth, and that the sheared surface may be propagated upwards through the zone of flow.

to the zone of fracture and even to the surface of the earth. In that case, the plastic shear would give way to true fracture near the surface.

It is only by a careful study, not only of the waves produced by earthquakes and of the permanent displacements which occur in them, but of the actual movement along the planes of fracture,

that we shall be able to discover what an earthquake really is. For the present, we must be satisfied with knowing that it is an elastic process; that it is usually destructive only within a very restricted belt, and that it is probably produced by the sudden release of a regional strain within the crust of the earth.

HEALTH EXAMINATIONS AND CANCER

By Dr. FRANKLIN H. MARTIN

DIRECTOR-GENERAL, AMERICAN COLLEGE OF SURGEONS; CHAIRMAN, BOARD OF DIRECTORS, GORGAS MEMORIAL INSTITUTE

COMEMLNESS of personal appearance is inconsistent with ill health. All men can not be handsome and all women can not be beautiful, but every man and every woman can have an interesting personality and a comely body and become an efficient citizen. However, such a wholesome picture can not be maintained with a defective body.

There is no economy in sickness. If every organ of our bodies were as conspicuous as our teeth, the defects of which are apparent to all every time we open our mouths, many sensitive people who are now harboring disease would seek comeliness and not advertise the evidence of unfitness.

Since I was born—and perhaps also since many of my listeners were born—the practise of medicine has been transformed from a mere art to an exact science. With our modern diagnostic facilities, the educated doctor of medicine can make an accurate diagnosis. An examination conducted by such a doctor will reveal your bodily ills; it will reveal diseases in their earliest stages when they are amenable to cure.

The American College of Surgeons—which consists of 10,733 leading surgeons and surgical specialists—has organized a program of prevention of disease. Sectional meetings of the College are held

periodically in various parts of the United States and Canada. One phase of these meetings is a community health session, at which a group of skilled physicians, surgeons and scientific specialists make short, heart-to-heart talks to the people and advise them how to keep well. They tell the people about the prevention and cure of disease, in other words, all the things that doctors, as partners of the people, are qualified to discuss interestingly and understandingly.

First, our speakers tell you that in 1916 the great hospitals of the country were taken into partnership by the College and that we have expended a total of one million dollars to achieve the goal of proper hospital care of the sick and injured. Hospitals, to secure approval, must meet a standard that has been fixed by the College. This standard insists, as a minimum, that membership upon the staff shall be restricted to physicians and surgeons who are graduates of medicine in good standing and legally licensed to practise scientific medicine, who are competent in their respective fields and worthy in character and matters of professional ethics (and under no circumstances irregulars); that the staff shall meet once a month to audit the medical and surgical work conducted in the hospital during the preceding interval; that

accurate and complete case histories shall be written and filed so that a record of the procedures of each member of the staff may be available at all times; that modern scientific apparatus shall be provided, and that an approved clinical and pathological laboratory shall be maintained to insure facilities for correct diagnosis.

The College does not obtain its information about hospitals through correspondence, or local or general committees. Actual surveys are made by salaried employees of the College—graduates of Class A medical schools, men of maturity with an extensive training in clinical work and hospital administration. These representatives send disinterested reports of their findings to the central headquarters, where all data are reviewed and the hospital rated.

One in every ten of the people who are within sound of my voice will require hospital care within the next twelve months. Will you seek one of the hospitals approved by the American College of Surgeons, or will you select one of the three thousand hospitals that have not met these reasonable requirements?

Second, our speakers present convincing proof of the benefits that will accrue to you and to your families if each of you will insist upon an annual or semi-annual health audit by your own family doctor, a careful and scientific inspection of every organ and every part of your body—that most intricate machine—in order to discover any defects in its mechanism.

Third, they tell you something of the diseases that are preventable, and they give you information that will enable you to recognize such diseases if they should reveal themselves between your regular inspections so that you may seek immediate relief. Oftentimes, if diseases are discovered early enough, precautionary measures may be advised and medical or surgical treatment may be obviated.

Fourth, they warn you that subtly developing maladies—heart disease, kidney diseases, diabetes, high blood pressure, stomach ulcers, diseases of the female pelvic organs and malignant diseases—may be promptly arrested and cured if they are diagnosed in their earliest stages.

Fifth, they give you information in regard to nutritional irregularities which cause obesity, leanness, skin blemishes, sallowness and other uncomely manifestations.

Sixth, they tell you that cancer is curable, and illustrate the fact by presenting records of many thousands of cures. They tell you of the apparent signs of cancer, and enlarge upon important details of cure. They tell you of the various stages of cancer so that you may seek scientific advice and forestall its development before it reaches the stage of incurability; they advise you to seek proper treatment of cancer, in whatever stage of development, that you may not, through ignorance of symptoms, fail to take advantage of scientific advice during the curable stage, and also that you may secure palliative treatment that oftentimes prolongs life and secures freedom from painful symptoms.

Many within the hearing of my voice may not be familiar with the early signs of cancer. They are as follows. Listen and remember.

A neglected skin blemish or persistent soreness may become a skin cancer. A small lump in the breast is a danger signal, and the family physician should be consulted at once. The lump may be the forerunner of an incurable breast cancer. Persistent indigestion or stomach distress are among the early symptoms of cancer of the stomach, and cure may be effected and progress arrested by immediate attention. Unnatural, irregular hemorrhages from any portion of the body should lead one to consult the family doctor immediately. There are other signs, but these are the outstanding ones.

Men and women, why not be on the safe side? Why wait for danger signals? Go to the human engineer, your own family physician, once in six months and have the human machine thoroughly inspected. Then you will be safe from all diseases. If you should be developing a cancer, it will be discovered in its very earliest stage—when it can be cured.

At a recent meeting of the American College of Surgeons, an innovation of outstanding importance was initiated. As a part of the scientific meetings of the college, thirty of the leading specialists of medicine and surgery reported actual cures in 4,348 cases of cancer—patients who were treated from five to twenty years ago and who were definitely cured of cancer.

In addition to the cures reported at this meeting by this limited group of specialists, the American College of Surgeons, through its committee on the treatment of malignant diseases, presented records of 1,263 additional cases of cures of five years or more which have been added to the archives of cures of malignant diseases.

The College, through its Department of Literary Research, also obtained from the literature reliable recent reports of 3,089 additional cures of cancer. The grand total of cancer cures which were reported by the College on October 20 was 8,840, and our survey was by no means an exhaustive one. This means a saving of approximately sixty thousand years. This innovation in the study of cancer was inaugurated by the college to impress upon every one the fact that cancer is curable by the use of the well-known and established methods of treatment that are approved by the profession of scientific medicine.

May I emphasize the fact that if every case of cancer could be diagnosed early and treated properly in its incipiency, the present annual death rate from can-

cer, now recorded as 150,000 in the United States and Canada, would be reduced by at least 33 per cent. or 50,000 per year. This early diagnosis and early treatment, may I again emphasize, can be insured only if the individual takes the precaution of submitting himself to an annual, or better, a semi-annual health audit, conducted by his own scientific family doctor.

Other beneficial results will accrue from this dissemination of proof of the curability of cancer. The scientific medical profession will be spurred on to ever greater efforts in its research into the cause of cancer, and in advocating early diagnosis; the discouraging psychosis that now exists in the minds of the public will be dispelled; a consciousness that cancer is curable will be established in the minds of all; fear will be displaced by a spirit of hopefulness; and every victim of cancer or suspected cancer will present himself for early diagnosis so that any and all diseases may be discovered in their incipiency, when they are amenable to treatment and cure.

Remember that a great disinterested body, the American College of Surgeons, has announced authentic cures of cancer as follows:

Pelvic organs	1,948
Breast	3,634
Bladder, kidney, and other genito-urinary organs	439
Colon and rectum	116
Thyroid	165
Larynx	50
Mouth	867
Stomach	356
Skin	866
Bone	90
Other classifications	309
Grand total of cancer cures five years and more	8,840

Remember also the slogan—"Cancer is curable"; and remember, too, to present yourself to your scientific family doctor for an annual or semi-annual health audit.

SCIENCE AND GOVERNMENT

By Dr. HUGH S. TAYLOR

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NATURAL resources, especially the mineral resources of the world, are an international responsibility, as has once more been emphasized in a recent radio address¹ by Professor R. M. Field, of the Geology Department in Princeton. Irregularity in the distribution of such resources throughout the nations of the world is a factor of manifest importance in the problem of international friendships and hatreds. The problems that arise thereby are obviously such as to demand cooperation not only of statesmen, diplomatists and economists, but also of scientists—a new technique in international affairs.

The difficulties attendant upon the solution of such problems are intensified because progress in scientific achievement may profoundly modify the extent of power accruing from the possession of a raw material. An excellent example of this is to be found in Chile saltpeter. This naturally occurring source of nitrates, required alike for peace-time agriculture and war-time explosive, was, prior to 1914, almost exclusively the monopoly of the republic of Chile. Chile saltpeter was carried in sea-borne consignments to the civilized countries of the world. This sea-traffic was an important consideration leading to the construction of the Panama Canal, with its accompanying international problems. The export tax upon the saltpeter was adequate revenue for the conduct of all state business in Chile. Her battleships were the most modern among the fleets of the South American Republics. To-day all the great nations of the world are drawing supplies of fixed

nitrogen from the air. Chile's contribution to nitrogen production and consumption was but 23 per cent. in 1929, as contrasted with 50 per cent. in 1913. The direct synthetic ammonia process, an industrial development from fundamental principles of chemical equilibrium, initiated by Professor F. Haber, of the Kaiser Wilhelm Institut in Berlin, was brought to technical development in Germany in 1913. The year is worthy of note. In 1929, as much as 44 per cent. of the nitrogen production and consumption was from the synthetic ammonia process. Chile is suffering from governmental troubles with increased internal taxation necessary. The curtailment of saltpeter exports is a factor, also, in depressed shipbuilding and ship-operating nations, indirectly affects export trade of many nations and is thus a familiar example of general depression conditions in the world to-day. The point to be emphasized is, however, that this condition arises not from an accident of monopoly in world resources but from the interplay of scientific progress with economic and indirectly with political and social conditions.

All monopolies of raw materials may be exposed to similar threats from technical progress. During the Great War, Germany devised ways and means to be independent of the control of the world sulphur market by the United States. New methods of deriving sulphuric acid from materials available at home were evolved. Germany and Great Britain are striving at the present time to derive synthetic oil fuels from coal, to offset the advantages accruing to the

¹ Included in the present number.

United States from her production of 71 per cent. of the world's petroleum; alternatively the use of powdered coal as a substitute for oil fuel is being intensively studied. In the opposite camp, the development of synthetic rubbers, such as "Duprene" by E. I. du Pont de Nemours and Company or "Thiokol" by the Thiokol Corporation, is evidence of an intent to mitigate the rigors of Dutch and English rubber control. From an earlier period, the successful syntheses of indigo and of camphor in the laboratories of Germany may be cited as of decisive significance in the former monopolies of India and of Japan respectively in these commodities. The tremendous recent developments of synthetic textiles, such as rayon, is a further factor in the economic condition of the Japanese nation, of concern to its silk industry, which may be of significance in the recent international activities of Japan.

It should be abundantly evident, therefore, that public affairs and international relations are being more and more divorced from the classical rules of international diplomacy and are becoming increasingly susceptible to conditions imposed not only by accident of materials distribution but also by excellence of scientific and technical achievement. Chemistry appears to be in international policies to stay. Atomic disintegration and the harnessing of atomic energy, when they arrive, will still further harass the economist and statesman. It, therefore, behooves those

responsible for the training of future generations in government to take cognizance of this definite trend in human affairs. With a few conspicuous exceptions, the wide spaces of the earth are explored and claimed. The age of discovery is giving place to the age of exploitation. Science is at once the most potent and unpredictable weapon for such exploitation. Students of public affairs and international relations must, of necessity, become increasingly understanding in the scientific point of view. It is with some such thoughts in mind that the undergraduate of to-day should approach his subjects of study if he be minded to embark upon a life of public or international service. Let him in this wise examine the curricula which are suggested for his training in such fields of effort. They may suggest to him the desirability that before he pass out from the undergraduate years to the larger opportunities of life outside he would do well to accumulate at least the fundamentals of those scientific subjects which all too definitely are of importance in problems of human affairs and all too obviously are neglected in the present organization of educational efforts to this end. It is essential that, in the problems of government in the future, due attention shall be paid to "Science comforting man's animal poverty and leisuring his toil" . . . "working back to the atoms, she handleth their action to harness the gigantic forces of eternal motion, in serviceable obedience to man's mortal needs."

THE FUNDAMENTAL UNITS OF THE PHYSICAL WORLD

By Dr. RUDOLF W. LADENBURG

BRACKETT RESEARCH PROFESSOR OF PHYSICS, PRINCETON UNIVERSITY¹

MODERN physics studies the properties and the structure of the atoms and molecules; for the atoms which form the molecules and build up every substance are not indivisible, in spite of their name. What are their building stones? Up to last year we thought that they were the units of positive and negative electricity and that these were quite different in mass and in size; that the smallest amount of positive electricity, the so-called proton, was always connected with the mass of a hydrogen atom and that the unit of negative electricity, the electron, had a mass 1,800 times smaller than that of a proton.

These are the two fundamental units of the atom, formed according to the famous ideas of Rutherford and Bohr; nearly the whole mass being positively charged, the "nucleus," in the center, surrounded by moving electrons which rotate around the nucleus like the planets around the sun.

There is a wealth of spectroscopical and chemical facts arranged on the basis of this picture. Perhaps the most beautiful result is the long-sought explanation of the periodic table, where the 92 chemical elements are ordered according to their atomic mass. The number which each element carries in this table—hydrogen (1), helium (2), lithium (3) and so on, up to uranium, number 92—is the number of positive charge units carried by the nucleus and at the same time the number of negative electrons which surround each nucleus. And the similar

properties of the elements which belong to the same vertical group—the alkali metals lithium (3), sodium (11), potassium (19), etc., or the rare gases helium (2), neon (10), argon (18) . . . are to be understood by the similar arrangement of the electrons in the outside shells or groups.

Now, the picture of these rotating electrons is not correct—it has been changed and improved to a large extent by the much-beloved quantum and wave mechanics, and yet the Rutherford-Bohr idea does not lose its importance. The importance of an idea does not lie, as Planck said in a recent lecture, in the amount of truth—it lies in the amount of fruitful work which the idea generates, and the fruitful work generated by Rutherford-Bohr's ideas is enormous. The views of that which is true change; the experimental facts remain.

The problem of modern physics is no longer the constitution of the whole atom; we have no doubt that the picture of the nucleus, which contains the greater part of the mass, the positive charge surrounded by the negative electrons, and the quantum-mechanical description of the action between these particles, is capable of explaining most of the chemical and physical facts. The most urgent question in physics is now: What is the structure of the nucleus? What are its fundamental units?

There is no doubt that the different nuclei of the 92 elements are not 92 different units, they all contain as many protons of mass 1 as the atomic weight indicates. If the atomic weight is not a whole number, that is, not a whole mul-

¹ Formerly in the Kaiser Wilhelm Institut für physikalische Chemie und Elektro-Chemie in Berlin-Dahlem.

tuple of the hydrogen mass which is taken as unity, it is because the elements are mixtures of different species. These are the "isotopes," so called because they occupy the same place in the periodic table, and the mass of each atomic species is very nearly a whole number. Thus the old idea of Proust is confirmed by modern atomic physics. The radioactivity of the heaviest elements—uranium (92), protactinium (91), thorium (90), actinium (89) and radium (88)—teaches us more about the nucleus. For these elements disintegrate spontaneously—they go over into other elements, either of lower atomic number and mass while emitting very fast alpha-particles that are nuclei with mass 4 of the element number 2 called helium, or they go over in an element of the same mass but of larger atomic number while sending out a so-called beta particle that is a negative electron, the other brick of the atom.

These facts have been known for a long time. But it is also possible to disintegrate some nuclei artificially. By bombarding light elements, as numbers 5, 7, 9, 13, with alpha particles given off from radioactive substances, Rutherford and his collaborators showed, about 14 years ago, that they are transformed into other elements. The alpha particle (the helium nucleus) usually sticks to the bombarded nucleus and this gives off a proton—a hydrogen nucleus. That is a great step forward in our knowledge of the nucleus.

The last year brought us some new and very important discoveries in this line of research: besides the proton, a new unit was found which is given off by some elements when bombarded by fast alpha particles—an uncharged particle of the mass of the hydrogen atom, the so-called neutron, which may be the element number 0 hitherto unknown, and yet expected by different theoretical considerations. Furthermore, *purely*

artificial disintegration was discovered. The alpha particles which were used before as bullets for bombarding the atoms are still natural fragments of radioactive substances. An even more powerful tool for disintegration are the protons themselves, artificially generated by ionizing hydrogen gas, and accelerated by means of potentials of some 100,000 volts. In bombarding some light elements with such fast protons, one obtains alpha particles of the enormous energy of some million volts emerging from the bombarded atoms. The lithium nucleus, for example, contains 3 positive charges and seven protons. When hit by a fast proton it gives off two alpha particles of about 8 million volts. This means that the lithium nucleus catches a proton and breaks up completely, for the newly-formed alpha particles are helium nuclei and contain as many protons and positive charges as the lithium and proton together. But their masses are somewhat less than the masses of the lithium and the proton. This mass difference just accounts for the gain of kinetic energy of two times 8 million volts; for according to one of the fundamental discoveries of Einstein, mass can be transformed into energy and *vice versa*. Otherwise the formation of the 8 million volt alpha particles would be a complete breakdown of the conservation of energy and we could not understand it at all. Indeed, these experiments, carried out by Cockcroft and Walton in Rutherford's laboratory in Cambridge, are perhaps the most beautiful proof of the Einstein mass-energy relation. So the energy stored up in the lithium nucleus is transformed into useful kinetic energy. As a matter of fact, the efficiency of this wonderful process is very small indeed. For the size of the nuclei is so small that we need two hundred million protons of half a million volt energy for a single hit of a lithium nu-

cleus. Therefore, only a vague hope remains that it may be possible some time from now to make this process useful for practical purposes.

On the other hand, the scientific importance of such experiments can scarcely be overestimated, and that is the reason why many scholars are engaged in high voltage work. I may mention the Van de Graaff electrostatic generator, described in this journal some months ago, which was constructed in the Palmer Physical Laboratory. Dr. Van de Graaff himself is now constructing a very large generator for about 10 million volts at the Massachusetts Institute of Technology. A modification of his machine, for use at high pressure, built by Henry A. Barton, D. W. Mueller and L. C. Van Atta, and able to produce one million volts, is still here. That same reason induced us to install in this laboratory a large transformer-kenotron outfit for producing about 500,000 volts. This has the advantage of great steadiness and of about 30 times more current than the Van de Graaff generator. The number of disintegrated atoms can therefore be increased many times, and important problems can be investigated which appear to be hopeless with a small amount of current.

On the other hand, the higher the energy of the bombarding particles, the more new and striking effects may happen. The last important and surprising discovery in physics was obtained by using the very penetrating cosmic rays, recently announced by Carl D. Anderson, Pasadena, California, and by P. M. S. Blackett and G. Occhialini, of Cambridge, England.

The question of the nature of these rays is not yet settled; it seems that they are composed partly of charged particles and partly of electromagnetic waves of x-ray type, only very much more penetrating than the hardest x-rays. There is no question that some of these particles, or say quanta, contain the very high energy of some billion volts—that is, about 1,000 times more than we are able to produce to-day. Now it is found that these quanta or particles disintegrate atoms—why should they not when protons of only 100,000 or even 15,000 volts energy do? But the very astonishing and quite fundamental discovery is that the particles which are produced or released by this process are positive electrons of light mass, christened positrons—it means positively charged particles of much smaller mass than a hydrogen atom or a proton.

Hitherto, as I pointed out at the beginning, electricity was considered to be very asymmetrical: the negative electron of very small mass as the unit of negative electricity and the proton of 1,800 times larger mass as the unit of the positive charge. Now, the positive electron appears, which seems to be a better counterpart of the negative electron than the proton, and this similarity between the positive and negative charges is more satisfactory from a philosophical standpoint than was the former picture. But the question now arises: Is the neutron a fundamental particle rather than a positive proton and a negative electron in a close combination, and is the proton perhaps a complex particle consisting of a neutron and a positron? What are the fundamental units?

IS SCIENCE EXACT?

By FREDERICK H. LORING

LONDON, ENGLAND

LORD BIRKENHEAD on one occasion, in giving an outside opinion, remarked that science was both exact and exacting. Those on the inside might be pleased with this statement, but amongst themselves they have to admit that, while in many fields of research very great precision obtains, there are some dense fogs hanging over certain advanced phases of the subject which darken the view and so prevent one from seeing clearly or exactly what takes place. At the same time conjectures based on many considerations are made and theories mathematically formulated. These theories are being put to the most exacting tests imaginable by those interested in their welfare, and it should be just as much a pleasure to confirm a theory as it is to furnish data which completely upset it. In this way the fabric of science is constantly being strengthened and the theories recast or new ones supplied. The late Lord Birkenhead's dictum is just as much an ideal aim as ever it was.

So much for a general statement; but what are the particular inexactitudes, if they may be so labeled, that are, or have been, exercising the minds of men of science?

THE INEXACTITUDES

The theory of relativity proved Newton's theory to be inexact, for the former theory showed that more experimental facts could be consistently coordinated. This theory also helped to abolish the older conception of the ether.¹

¹"The theory of relativity in effect requires that it shall be impossible to decide as to whether an ether exists or not, either by these or by any other purely mechanical considerations; the equations of radiation and absorption of energy are precisely the same whether the energy is radiated into, and absorbed from,

and thereby produced a mental hiatus, so to speak, and the problem of supplying a suitable ether has been left unsolved, and in its place are the mathematical equations which work well in many ways; so that, for all practical purposes, no space-filling material-like medium is required for the functioning of the phenomena of light or radiation or even of gravity. Space thus becomes endowed with characteristics peculiar to differential equations, and some begin to think that the mind can not properly grasp such matters apart from the mathematical working, nor should it attempt to do so. It is not a proper question to ask or to solve, any more than in the Christian religion it is proper to ask who made God. As a matter of fact the whole trouble here is the exactness of the principles evolved by Einstein as supported by the contributions of H. A. Lorentz, Minkowski and others, speaking particularly of the special and general theories of relativity. These epoch-making theories solved so many problems at one stroke that there was left no choice about it but Hobson's. They were, moreover, all-embracing for large-scale phenomena.

The mind of man is never quite satisfied, and one may expect to see the ether reinstated some day. Just what this ether will be is not known. Sir Oliver [redacted] an ether or empty space. The analysis we shall now give will show that the existence or non-existence of an ether is wholly irrelevant to the question, so that if our analogies break down, it is not on the question of the reality of the ether. Leaving analogies behind, we proceed to discuss the real physical problem at issue." This is taken from Sir James Jeans' "Report on Radiation and the Quantum Theory" (1924), page 5, being the concluding words of the introduction.

Lodge is a staunch believer in the ether and it is to be hoped that it will be said: Lodge was quite correct in his general belief. Such an advance as this need not, however, disturb the relativity principles which seem so well established by experiment. Einstein himself would no doubt subscribe to the idea of an ether, if he has not already done so; but at present it can not be definitely defined in a way satisfactory to the lay mind, or even to the mind of the physicist, so it is of necessity left out of the picture. In fact, it is not needed in wireless work. It becomes a meaningless label, and hence an inexact one from this point of view.

As in many advanced matters of physics, the words are not categorically definition-words, but expressions of speech which convey the state of affairs as understood by the context and the state of the art. The subject of the verb may even be truly missing, as in the case of the ether being the subject of the verb undulate, to cite an oft-repeated observation, but an inexactitude that is understood within the limits prescribed.

DEFINITIONS

It will be seen that in order to maintain a status of exactness the ultimate definitions have to be avoided. If one sets to work and invents definitions of matters about which too little is known, as research progresses one is apt to be faced with terminological inexactitudes of one's own making. For this reason definitions are not as a rule regarded with special favor. It is true, however, that the definition could be so drawn up as to give satisfaction to all concerned; but it is difficult to do this, and such elaborate definitions would involve statements tantamount in part to no definition at all. Some facetious person might then say: "This is the tune of our catch, played by the picture of Nobody"—to borrow a quotation used by Sir Arthur Eddington in his "The Nature

of the Physical World," page 292, where he discusses reality.

THE RADIATION DILEMMA

Coming now to the physics of the atom involving the scheme of affairs in giving out radiation when excited, there are some very perplexing matters that at once label the situation as hopelessly inexact; for, according to one established wave theory of light, correct answers are given to many optical phenomena implying an exact theory with mathematical computations exact to the finest measurement; but, when another set of optical experiments, relating more particularly to the origin of the light, that is to say, its quantum nature, are examined, it is found that the above theory does not fit the cases and the light has to be treated as made up of parcels or atoms of radiation; and here too exact results come out of the mathematical analysis, all according to the well-established laws or rules of the quantum theory.

Sometimes this dilemma is expressed as being continuity *versus* discontinuity, but perhaps it might be better to say spreading *versus* convergence. In further traversing some familiar ground, in the photoelectric effect the radiation seems of its own accord selectively to converge on an individual atom and cause an electron to fly out of the said atom; and this—the convergence without a lens being used—is opposed to experimental data, since no such convergence can be optically demonstrated. It has in a sense to be imagined and yet it is known that light inherently spreads.

This can be explained by assuming that radiation in space has no particular quantum property in itself except that it is like a host of radial lines emanating from a number of centers in the light source. Where these lines meet at one spot in sufficient number, whilst of the proper frequency, they make up the

quantum determined by the atom and then the electron is ejected with this energy. It is better, however, to consider this problem from the point of view of recent theories, as these solve other problems as well.²

SEVERAL NEW THEORIES

A set of powerful theories have grown into formidable proportions; but they seem to be equivalent, or they merge on common ground. The upshot of it all is that matter, the atom and the electron are fundamentally waves. Everything in the end analysis reduces to waves, the wave-equations satisfying the experimental facts, so that a wide variety of phenomena are amenable to this particular treatment, which in some phases is highly symbolic and involves mathematical processes of the most far-reaching kind. The principal names associated with this advanced development are: L. de Broglie, Dirac, Heisenberg and Schrödinger.

Yet the meanings attached to the mathematical operations become for the most part difficult or impossible of definition in terms of known phenomena. It is as if coarse phenomena could be described in terms of the same phenomena on a smaller scale until a state of affairs is reached when this type of description

² "The fundamental law of quantum-dynamics, that radiant energy is emitted and absorbed only in complete quanta, is no longer interpreted as meaning that the ether can carry radiant energy only in complete quanta, but that matter can deliver or absorb radiant energy only by complete quanta. It is matter, and not ether or radiant energy, which proves to be different from what we had thought." This statement appears in Jeans' report (cited in the previous footnote), page 80. Since this was written new experimental facts have perhaps modified the view just expressed, as the space devoid of matter may carry light quanta as more or less isolated units; but this interpretation may be at fault, so that Jeans' statement may still hold true. It is only by studying the experimental data and theories referred to in the next section that this statement can be reconciled, and then perhaps only with difficulty.

utterly fails and recourse to pure mathematics becomes necessary to carry on the analytical process. Then when the mathematical work is resolved back, as it were, the direction of the process of definition becomes reversed, and comparatively large-scale phenomena are definable in the new ultimate terms of the small-scale phenomena; hence the seeming incongruity; still, one sufficiently equipped is tempted to throw overboard all the old-time notions of things and to work with the newer ideas, which are largely equations and symbols. It all works. Yet some of the meanings attached to mathematical operations become impossible of pictorial definition. Thus, in the pursuit of exactitude the word-pictures have to be abandoned. The tune played by the mathematician is on mental instruments, but the reality it stands for has no corresponding picture, which brings the subject back to the "tune of the catch played by the picture of Nobody."

SCIENCE TOO EXACT!

The trouble with the advanced method of the kind herein discussed is that today it is too exact. The precise tools of the mathematician have been fitted to the secret locks of nature and these when unlocked reveal the most extraordinary state of mechanism, if it may be so called, that is quite beyond the hope of man's interpretation in terms of common things or even in terms of uncommon things. What is going to be done? This is no doubt a question latent in the minds of some advanced workers. It is getting too complicated for words, and when it all reduces to the most elaborate mathematics, what then? It is like expressing all the curves and arrangements of letters on this page mathematically. We need, perhaps, less exact science in fact. A science that is willing to forego some of the precision now attained and one which will give a working picture of things. Shall the

mathematician have to step aside for the artist who does things by an art that is not quite so difficult of mastery? Moreover, the artist's picture complete in the minutest detail appeals with integrated strength, whereas the mathematical conceptions are more like a futurist nightmare when attempts are made to translate them into pictorial effect—the tune is played by the picture of nobody.

THE PRINCIPLE OF INDETERMINACY

Notwithstanding, out of all this complex of mathematical analysis some comparatively simple ideas are emerging, and it is perhaps these that will save the situation, and the immediately-preceding statements will then be beside the point. Great interest is now aroused in the principle of indeterminacy of Heisenberg. It appears that in the search for truth underlying the movements of the electron in connection with the atomic state of matter, the precise position of the electron and its precise velocity can not be determined simultaneously. The uncertainty is axiomatic, and this calls to mind the uncertainty of the behavior of a given atom in throwing off a part of its substance and becoming an atom of another element which is the basis of radioactivity. Average results can be predicted, but the behavior of the individual is uncertain. The laws of the radioactive atoms are known, except that the particular atom that is going to disintegrate next is as uncertain as the drawing of a lucky horse in the Dublin Sweepstake.⁸

⁸ There is one feature bearing on the above that needs consideration. The contents of an egg before it is placed in an incubator does not reveal the potential structures of a chicken, yet when it is subjected to warmth, which is radiation, these structures develop systematically and a chicken is evolved according to type. The egg is therefore an example of determinism; and might not one say that the atom, being less familiarly known than the egg, is also an example of determinism? Or, to state it another way, the medium of the egg and the medium of the atom have in common

SCIENCE TERRIBLY EXACTING

In preface to the above it is believed that in mass operations statistical laws apply with great exactitude, but when getting down to individuals the laws appear chaotic. There is a human element in this behavior, as when the innermost workings of nature—even in inorganic chemistry and physics—are studied they appear to be quite erratic, just as the movement of a Mr. Jones or a Mr. Smith at a given instant can not be predetermined. Their average or daily movements can be accounted for or ascertained beforehand, but just what Mr. Jones is going to do the next minute no one can say. In the Scotland Yard of science the principle of the alibi is indeterminate and has to be abandoned.

Drawing a lesson from this, exactitude leads to inexactitude, so that coming back to Lord Birkenhead's dictum it should perhaps be written: Science is not exact but terribly exacting. It must be known where the inexactitude lies and such knowledge involves research of the most exacting kind. Eddington even goes so far as to intimate that the application of a law of inexactitude may be productive of far-reaching results. To discover new principles from very exact experimental work coupled with mathematical analysis are achievements that fully justify the work and point even to greater advances in fundamental knowledge being possible in the immediate future.

the property of storing in their structures potential qualities, so that their behavior is deterministic. The answer to this is probably that, whereas, we do not know the so-called egg-substance-structure in a fundamental sense, we do know something about the structure of the atom fundamentally, and it is this knowledge that has given rise to the principle of indeterminacy. Moreover, in the atom the indeterminable quantity is a single entity, for example, the electron; whereas, in the egg the determinism applies to large molecular groups, just as it does with atoms in mass formation or in large numbers, as stated above. The egg can not therefore serve as a criterion for judging the doctrine of indeterminacy. .

CONCERNING THREE-EYED FISHES

By FRANK E. FIRTH

U. S. BUREAU OF FISHERIES

IN the November-December issue of *The American Naturalist*, Vol. lxii, 1928, Dr. E. W. Gudger, of the American Museum of Natural History, New York City, carefully described certain known instances of the occurrence of three-eyed embryos. He also described the case of an adult haddock with three eyes, which seems quite a questionable record. Although several photographs of it are shown, the study of the other occurrences seemed necessary. After exhausting the literature on this subject, it was shown that three-eyed forms occur as embryos only, with the exception of one instance. In this, however, the author, Dr. Meek, obtained the confession of the party who so cleverly "faked" the specimen.

Dr. Gudger painstakingly, cleverly and rather accurately deduced that the specimen in question was no less than a skilfully prepared "fake." Although he was without proof at the time he wrote, he was right.

A year after publication of the article mentioned above, Dr. Gudger's attention was called to the "Ruminations of a Codfish Forker," in *The Fish-*

ermen's Own Book,¹ where the following statement was printed:

Seems there was a three-eyed haddock brought in at T-Wharf. This don't impress me so much. I once had a buddy on one of these schooners, and he told me how he slipped up on a feller once, was sitting off by himself on the trip home. This old feller was a great one for whittling, real handy with a knife. Well, he was working on the head of a haddock, real careful like, when he got through, he brought a fish eye out of his pocket and slipped it in the hole, just as neat as you please. Never saying a word, he drops the three-eyed haddock back with the other fish, and the next day, folk was coming from far and wide down to the fish pier to see the latest wonder of the world, the three-eyed haddock.

Thus was substantiated the conclusions arrived at by Dr. Gudger at that time after a study of the photographs and literature. Accordingly this latest exposé was published in the *Annals and Magazine of Natural History*.²

During the summer of 1930, while stationed at the Boston Fish Pier, Boston, Massachusetts, on a mackerel investigation, I chanced one day to bring up

¹ New York, Vol. viii, No. 4, p. 28, 1928.

² London, Ser. 10, vol. vi, p. 41, July, 1930.

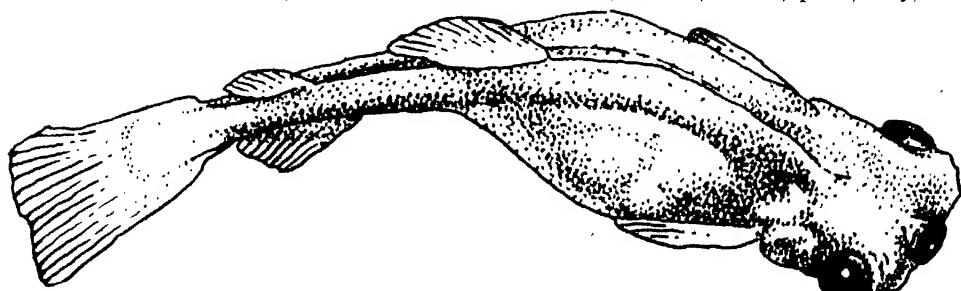


FIG. 1. A THREE-EYED TROUT EMBRYO, LENGTH ABOUT 20 MM. THIS IS A SPECIMEN OF WHAT EVIDENTLY BEGAN AS A TWO-HEADED FISH, THE THIRD-EYE BEING FORMED BY THE FUSION OF THE TWO INNER EYES. (After Gemmill, 1912).

the subject of deformities and irregularities so often encountered in fishes. In the group was one of the real "old-timers" of the pier, who recalled the incident of the three-eyed haddock some years ago and told how certain scientific men were at a loss to explain its cause. Then, with a mirthful gleam in his eyes, he confessedly continued: "I don't know what prompted me to do it, but on the way to the store with a cart of fish [haddock] just received from a vessel, I stopped, removed a haddock and cut a hole in the middle of the head of it. Next, I removed an eye from another fish, leaving a long stalk on it [the optic nerve] and forced it into the cut hole of the first specimen. Placing it in the top layers of the fish in the cart I continued on to the store. Within a very short time it was 'discovered' and you know the rest."

Thus, after a few years of doubt, we have the truth and necessary proof of the occurrence of three-eyed haddock, not fashioned by nature but rather by man.

The first intimation of the discovery of the so-called three-eyed haddock was in the *New York Herald-Tribune*, October 9, 1927, when the fish was described and recorded. Due to the great similarity in the methods each man employed in creating these fish, it is quite probable that each one was truthful but that only one ever got into the newspapers.

In connection with this there is another very interesting "origin" of a similar abnormality. This too happens to be by an English scientific man, but it is *not* Dr. Meek, whose case has been mentioned previously. It concerns a Dover or black sole, and was published



Wide World

FIG. 2. A DORSAL VIEW OF THE HEAD OF THE THREE-EYED ADULT HADDOCK, THE FISH CONCERNED IN THIS ARTICLE. THE SHARP DIFFERENTIATION OF THE SCALY SKIN SURROUNDING THE CENTRAL EYE IS PLAINLY SHOWN HERE.

in *Fishing News*, Aberdeen, Scotland, July 19, 1930, as follows:

An English scientist had a friend on board a trawler who used to take unusual specimens ashore to him. In payment for these specimens he (the fisherman) was always given a drink. One day the trawler friend had no specimens and he was real thirsty, so he slit a small hole between the two eyes of a witch sole and slipped a haddock eye into it, and behold a three-eyed witch. The trawler friend got his drink all right, and the scientist had such a rare specimen that he wrote a thesis on it. He discovered after his paper had been printed and circulated that his friend was a gay dog.

And there is yet to be found a genuine three-eyed adult fish.



PROFESSOR ELIHU THOMSON

WHOSE EIGHTIETH BIRTHDAY WAS CELEBRATED AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY ON MARCH 29 BY A CONFERENCE, A HISTORICAL EXHIBIT AND A TESTIMONIAL DINNER. AT THE CONFERENCE PAPERS WERE READ BY PROFESSOR JOHN C. SLATER AND DR. KARL K. DARROW, AND BY PRESIDENT KARL T. COMPTON, WHO MADE AN ADDRESS ON THE "SIGNIFICANCE OF PROFESSOR THOMSON'S WORK IN THE DEVELOPMENT OF ELECTRICAL ENGINEERING." AT THE DINNER THE SPEAKERS INCLUDED GOVERNOR JOSEPH B. ELY, MR. GEORGE B. CORTLEYOU, MR. H. P. CHARLESWORTH, DR. HARVEY W. CUSHING, DR. VANNEVAR BUSH, DR. DUGALD C. JACKSON, DR. HOWARD McCLENAHAN, DR. E. W. RICE, JR., AND PROFESSOR THOMSON.

THE PROGRESS OF SCIENCE

THE CONTRIBUTIONS OF PROFESSOR THOMSON TO ELECTRICAL ENGINEERING

PROFESSOR ELIHU THOMSON, scientist, inventor and dean of living electrical engineers, was eighty years old on March 29, 1933. During his lifetime, rich in accomplishments and inventions, has come the development of the electrical industry of which he is one of the great pioneers--the last of the American "Big Four" of electricity, the other three being Thomas A. Edison, Charles F. Brush and James J. Wood. At eighty Professor Thomson is still active and alert and devotes long hours to the direction of the important research problems in the laboratory of the General Electric Company, at Lynn, which bears his name. In the years which he has given to electrical science--more than half a century--Professor Thomson has been granted more than 700 patents in the United States and he holds many foreign patents as well.

Elihu Thomson was born in Manchester, England, and came with his parents to this country when he was about five years old. The boy began his education in Philadelphia. From his father, an engineer and skilful mechanic, Dr. Thomson inherited his ability in the mechanics arts and the never-to-be-satisfied curiosity out of which have come many of his great contributions to science and engineering.

Already, as a boy, he began making models of physical apparatus. In his office he still has a frictional electrical machine which he made at eleven years of age and the principal part of which was an old wine bottle which could be rotated by a crank. It is told that he demonstrated the machine to his father, who was not particularly impressed by the tiny sparks which it produced. Elihu Thomson, however, desired to show his father that his machine after all was not merely a plaything. So he

used it to charge several Leyden jars. He then repeated his former demonstration to his father with such effectiveness as almost to flatten him by the shock.

Upon having completed his education, Elihu Thomson became connected with the Boys' Central High School in Philadelphia and at the age of twenty-three was made a full professor of chemistry and mechanics. He was a beloved lecturer and had the ability to keep his students' interest fully. It was during this period that he also gave a series of scientific lectures at the Franklin Institute in Philadelphia, holding his audiences fascinated by his experiments in electricity. His interest in these years was centering definitely in the field of electricity, and it was in 1876 that he demonstrated his first dynamo at the Franklin Institute.

With his colleague, Professor E. J. Houston, he continued the development of dynamos, and the one built in 1879 may be said to have been the basis of the arc-lighting system which became known as the Thomson-Houston system. In 1880, however, his association with Professor Houston ended and he moved to New Britain, Connecticut, where his patents for a time were exploited by the American Electric Company. Subsequently the business was moved to Lynn, Massachusetts, under the name of the Thomson-Houston Electric Company, which later (with the Edison General Electric Company) became the General Electric Company.

Professor Thomson's inventions and contributions to the development of electrical engineering have been many and varied. It would carry us too far afield to attempt to mention them all. The most important ones, however, are his developments of the dynamo with its automatic regulator and its commutator-spark-prevention device, usually termed



PROFESSOR THOMSON AND DR. E. W. RICE, JR.

WITH THE ELECTRIC DYNAMO BUILT SIXTY YEARS AGO. DR. RICE WAS A PUPIL OF DR. THOMSON AT THE CENTRAL HIGH SCHOOL OF PHILADELPHIA MORE THAN FIFTY YEARS AGO, AND THE TWO HAVE SUBSEQUENTLY BEEN CLOSELY ASSOCIATED IN THE WORK OF THE GENERAL ELECTRIC COMPANY.

his air-blast mechanism. The latter works on the principle of injecting a stream of deionized air at the instant the current passes through zero, thus making it impossible for the incipient alternating-current arc to become established. The principle which he here introduced is of fundamental importance and is indeed to-day incorporated in the design of large circuit breakers.

Another of his important electrical developments is that of the constant-current transformer, which made it possible to supply a series circuit containing alternating-current arc lights with a constant current, independent of the number of arcs which were used. Since most of the lighting at the time was done by arc lamps, it is not surprising that Professor Thomson also designed and patented a number of these, making

their automatic operation highly reliable.

Again, another electrical field where Professor Thomson has done outstanding work is that relating to metering of electric energy. He developed several types of recording watt-meters, or watt-hour meters, as they usually are called to-day. His designs at the present time practically monopolize the world's market. His meters are used wherever electricity is used, and it is said that around thirty million Thomson watthour meters are to-day in actual operation.

Although most of his work has been in connection with electrical devices, his contributions in the mechanical field have also been numerous. Thus in the years 1877 to 1881, jointly with his colleague, Professor Houston, he invented and patented the continuous centrifugal cream separator. This was a device ap-

plicable to the separation of substances of different densities, and has come into universal use in creameries as well as in the laboratory and elsewhere for centrifuging mixtures which it is desired to separate.

Another mechanical development in which Professor Thomson has been deeply interested is that of steam generation and its subsequent utilization in high-efficiency engines. In 1901 he obtained a patent for a "vapor generator" which was virtually a steam boiler and an oil burner combined into a very moderate-sized structure in relation to the output. In developing this boiler Professor Thomson had its application to automobiles in mind, but evidently it might be useful for many other purposes. One important feature in this connection is its ability to relight three hours after extinguishment simply by turning on the fuel supply. It seems, however, that his pioneer work in this particular field has never received the attention which it actually deserved.

Hand in hand with his work on the above-mentioned boiler was his development of a high-efficiency engine. In his patent of 1903 this is termed the "fluid-pressure" engine. It was a non-condensing reciprocating engine involving a somewhat novel principle in that the steam was permitted to flow in one direction only—from the intake to the exhaust—never turning back to come once more in contact with the heated surfaces. It gave remarkably good results. No

doubt Professor Thomson here laid down a new and important principle for engine design. Engines built on this principle are now generally known as "uni-flow" engines and have been manufactured and used to a considerable extent, especially in Germany.

It would be possible to go on elaborating on his electrical, mechanical and other inventions, but evidently space does not permit. Let it suffice to call attention to his work in a somewhat special field, namely, that of the manufacture and application of fused quartz. His early interest in optical instruments led to his intensive study and experimentation in this field, and many patents have been taken out by him since 1902. The methods perfected under his direction have proved markedly successful and permit the construction of quartz apparatus in size and quality hitherto unapproached. Its principal applications are optical lenses and mirrors, windows for deep-sea diving bells and for use as a transmission glass for ultra-violet light in hospitals and special lamps.

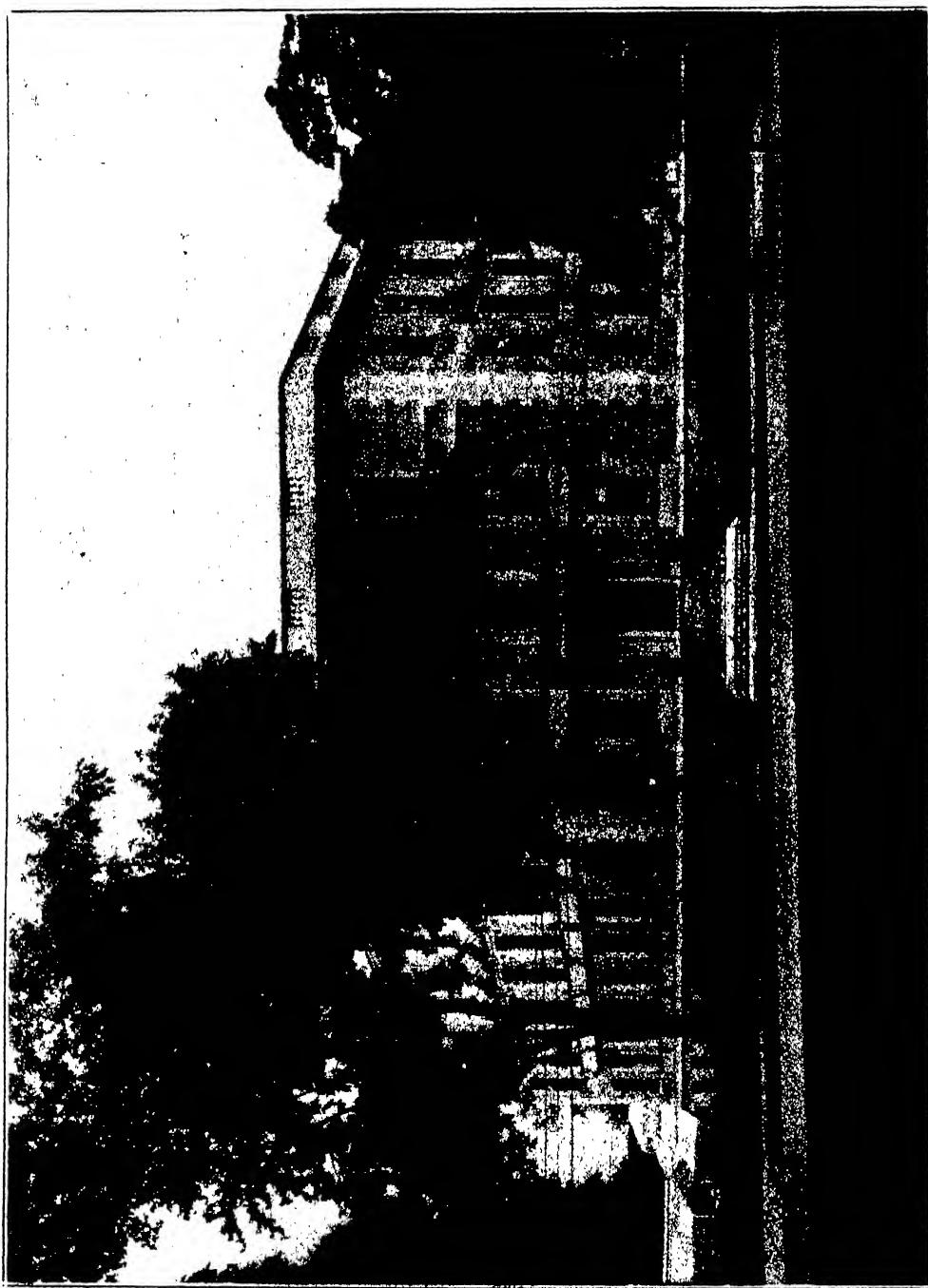
Professor Thomson possesses the constructive powers of the inventor, the thoroughness and soundness of a man of science and the kindly balance of the ideal philosopher, teacher and friend. This remarkable combination of qualities has endeared him to all with whom he has come in contact. Throughout his life he has set an example by which the younger generation may well profit.

THE NEW BOTANY BUILDING AND PLANT HOUSES OF THE UNIVERSITY OF TORONTO

THE botanical laboratories and plant houses of the University of Toronto, the provincial university of Ontario, were formally opened and presented to the university on June 8, 1932, by the Prime Minister, who is also Minister of Education of the Province of Ontario, the Hon-

orable George S. Henry. The first work, on the excavation, had been begun about fifteen months previously.

This new unit of the university's equipment is situated on the west side of the entrance to Queen's Park at the southeast corner of the university cam-



BOTANY BUILDING AND PLANT HOUSES FROM QUEEN'S PARK

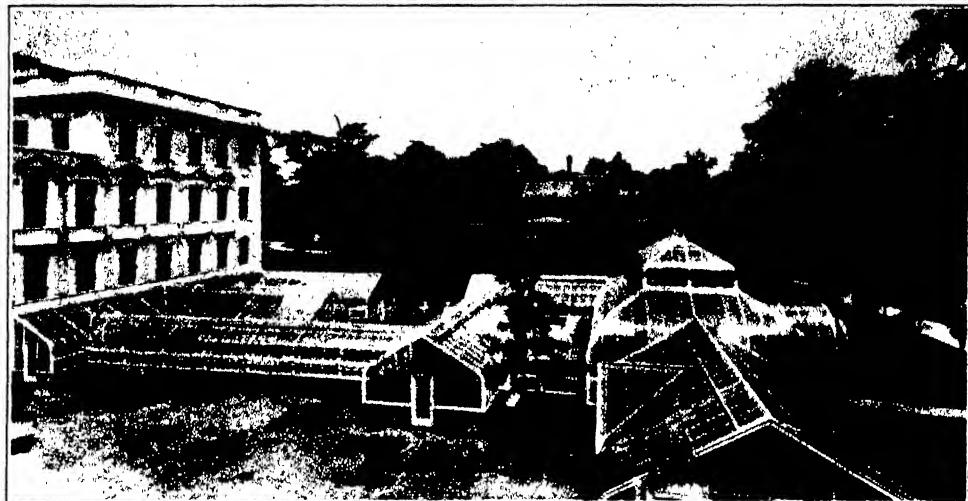
pus, the building facing the Ontario Legislative Buildings in the park to the north and the plant houses facing south on College Street. The building is a four-story Georgian structure, with a total floor space of 42,600 square feet. It is in the form of a hollow square open at one corner and is constructed of Ontario limestone—Credit Valley, with Queenston trim. The relief decoration of important panels is of botanical character—designed from familiar local plants, pine, oak, water lily, etc.

The main entrance opens into a small octagonal foyer with walls of Tyndall limestone, which is flecked with buff. It has a parquet floor of black, light gray and white marble. The halls have a three-quarter facing of buff brick and where traffic is not concentrated, are sufficiently wide to accommodate wall cases for the display of special class material. The trim and furnishings throughout are of birch and pine in walnut finish. Two fireproof stairways are located at opposite corners—one at the northwest and the other at the southeast. They open on the quad and serve ordinarily as extra entrances and exits for elementary and advanced students, respectively.

The main entrance for students is at the west side of the west wing, nearest the other university buildings. In the lowest story of this wing at opposite sides of the entrance hall are the large cloak-rooms for men and women and the lecture theater with seating for 180 students. This has an adjacent chart room and is two stories high. There is no gallery at present, but one can be added with entrance on the next floor, which will increase the accommodation by about sixty. On the main floor in this wing there is a lecture room for 60 students; on the second floor, a large laboratory with accommodation for 150, with adjacent preparation and supply rooms; and on the third floor a smaller laboratory to accommodate seventy stu-

dents, also preparation, storage and photographic rooms. These general laboratories are fitted with unit tables accommodating eight students—four at a side. The tables are acid-proof and are supplied with daylight microscope lamps (two to a table), gas and individual microscope lockers and supply drawers. There are five supply drawers in a tier at one side of each work place and two microscope lockers in a tier at the other side. The student of each class is given a key for one of the microscope lockers and one of the supply drawers. Each student has thus beside him all the equipment he needs and does not disturb the class in getting it. In the large laboratory, which is used for bacteriology as well as elementary morphological work, running water is also provided for each student. On all floors this west wing is separated from the remainder of the building by swinging doors in the corridor just east of the stairway, so that the noise and confusion of the coming and going of large elementary classes is restricted to this part.

The remainder of the building contains laboratories for advanced classes and private research, offices of the staff, library, herbaria and research rooms for graduate students, as well as the necessary workrooms, storerooms and machine rooms. The rooms for graduate students face the quad on all floors. Each has two windows and duplicate equipment. The main part of the lowest story is given over to the work of plant pathology under the direction of Professor D. L. Bailey; the south part to the potting rooms and office of the horticulturist. On the first floor, to the west of the main entrance, are laboratories for cytology; to the south, the laboratories for plant physiology, under Professor G. H. Duff. The south block on this floor contains the living apartments of the horticulturist. On the second floor, above the main entrance, is the library with the



GENERAL VIEW OF PLANT HOUSES

CORRIDOR HOUSE ON LEFT GIVING DIRECT CONNECTION WITH BUILDING ON LOWEST FLOOR LEVEL.

seminar room to the west of it; to the south, laboratories for forest pathology, and the staff room and office as well as private laboratory of the head of the department, Professor R. B. Thomson, and adjoining these in the south wing are the laboratory and the storerooms for work in morphology and anatomy. On the third floor, above the main entrance, is the herbarium of flowering plants; to the west are the seed laboratories under Professor H. B. Sifton, and to the south the mycology laboratories and herbaria under Professor H. S. Jackson.

The plant houses, which lie to the south, are attached to the building by a glass corridor extending the length of the south wing. As the floor of this corridor is on the same level as that of the houses and the ground floor of the main building, plants may be readily moved from one to the other, without being subjected to change of temperature, and by means of the elevator taken to any desired floor.

Opening on the east end of the corridor are the houses for plant physiology and immediately west those for plant pathology. Next comes a passageway

house in which propagation work is carried on. It connects the main group of houses with the corridor. This group comprises a number of individual houses with special temperature and moisture controls, suited to a variety of plant types. A palm or tropical house occupies the center of the southern range, to the west of which is the fern house and to the east the cactus or desert house. The part north of the latter is for plants of intermediate temperature requirements, and directly behind the palm house is one for cool temperature plants.

The houses cover an area of 6,476 square feet and are heated with hot water. This in turn is heated by steam from the central heating plant. In case of accident an oil-burning furnace cuts in automatically and an alarm sounds in the horticulturist's quarters. A well provides unchlorinated water and provision has also been made for the collection and storage of rain water.

One pleasant fact remains to be recorded. The total cost did not exceed the estimate, a little over \$500,000. There were at least two factors responsible for this. Plans had been in preparation off and on for twenty years, so

that there was practically no alteration necessary when the building was under way. In the second place, the cost of materials and labor lowered considerably between the time the appropriation

was made and the actual time of spending the money.

R. B. THOMSON
PROFESSOR OF BOTANY,
UNIVERSITY OF TORONTO

THE EFFECT OF SUNLIGHT ON THE GROWTH OF FLOWERS

CLASSIC myth had the Greek sun-god, Phoebus, turn himself into a shower of gold, to visit one of the numerous lovely ladies of whom he was enamored, when she was locked up in an inaccessible tower. So to-day the sun is able to visit the hosts of delicate woodland flowers that live only through his favors, by showering himself through the interlaced bars of the as yet unleaved tree branches.

It seems a trifle paradoxical that the flowers of the early spring woods should be so much like the flowers one finds in the semi-arid lands of the Southwest and the Rocky Mountains, yet such is the case. Some of them are of the same genera: violets, trout-lilies, buttercups, anemones, spring beauties, and many others. And even where they are not fairly close relatives, there are astonishing resemblances in general habit of growth.

The solution to the paradox is to be found in the fact that before the leaves are on the trees, the ground under them is not, properly speaking, in the woods. It is at least halfway in the windy, sunny open, subject to much the same illumination and the same evaporation rates as the prairie alongside or the chaparral a thousand miles away. Only when the leafy canopy has closed itself, excluding the warming sun and materially cutting down the force of the drying breeze, does the forest become properly a forest to the trees that grow underneath. Then it is that the spring flora—geraniums, phloxes, bellworts, hepaticas and all the rest—give way to the much reduced number of flowers that will consent to blossom in the deep shade of the summer woods.

This characterization of the spring woods as really touched with the tang of the desert is no mere impression. The difference between the woods of May and the woods of July has been scientifically measured. Several years ago sets of instruments for measuring the evaporation rate of water were placed in a typical strip of midwestern woodland along the bluffs of the Illinois River, and kept in operation from the first of May until nearly the end of September. The evaporation rate in July was high, as might have been expected. But a result that was not expected at all was that in the first week in May, when the leaves had not yet covered the oak trees, the evaporation rate was still higher!

Violets, buttercups, spring beauties, trilliums, Jack-in-the-Pulpit, Solomon's seal, May-apple, bloodroot, blue-eyed grass, Dutchman's breeches—these and a host of other lovely blossoms we instantly hail as gifts of spring. With hardly an exception, the flowers that star the woods just before and after Easter were prepared for our present delight during the summer that is past. They were paid for out of savings thriftily laid by during a former time of abundance.

Examine the underground parts of any one of the flowers named, or of almost any other spring flower you can find, and you will find a thickened root or rootstock or bulb or corm, or some other form of "storage organ," filled with starch like a potato or with sugar like an onion. This was formed out of the surplus food manufactured by the plant last summer—sometimes during several summers—when no flowers were in sight or in immediate prospect. All

winter through it lay under ground, compact energy of the sun fixed and hidden away, ready to be liquidated when the returning warmth and light of that same sun should give the word this spring.

Summer flowers, many of them, will be different. There will, of course, be plenty of perennials, long-lived and food-storing plants among them, but summer plants also include many annuals, plants that grow during one season from seed, form seed for the next year, and then die when frost comes. The longer time they have before their flowers become mature gives opportunity for this short life cycle to complete itself and still leaves next year's generation provided for in the scattered seeds.

Of course, the perennials par excellence are the trees, for these store their food in the exceedingly tough and long-lived wood of trunk and roots. It is for this reason, presumably, that most trees—alder and willow, maple and oak, dogwood and redbud, magnolia and tulip-tree and a host of others—are as truly spring flowers as are violets and buttercups.

March sunshine, and even February sunshine, have as much to do with bringing forth May flowers as have the traditional April showers. And it is not merely the sun's part in thawing the snow and ice of winter, nor his gifts of food through the sugar-making factories in the leaves, that bring about the miracle of bloom in spring woods and fields, but the long-neglected astronomical fact that in spring each day is a little longer than the day before.

For uncounted centuries people had seen the flowers spring up as the sun returned northward after his winter retreat. The connection of increased sunlight with the pleasures of spring

had not escaped even the oldest of peoples. From the Nile to the Baltic, from India to Yucatan, men made a god of the sun and invented myths of spring, some of them most poetical and beautiful.

But it was not until a short time ago that two scientists of the U. S. Department of Agriculture, Dr. W. W. Garner and H. A. Allard, discovered that the changing length of day is a potent control over the blossoming time of plants. They put numbers of different kinds of flowers and vegetables into a greenhouse equipped with shades and electric lights, so that they could give them a wholly artificial length of "day," making it at will longer or shorter than the natural day. They soon found that plants whose season of bloom came before midsummer were stimulated into flower production by increasing the light-period a little each day, whereas plants of naturally late flowering habits could be brought into bloom by daily shortenings of light. Typical "long-day" plants are crocus, hyacinth, iris, columbine, lily of the valley—all spring flowers. "Short-day" flowers include goldenrod, aster, chrysanthemum, sunflower—flowers of autumn and late summer.

Since these pioneer workers carried on their experiments, many other botanists, as well as commercial florists, have repeated the work and elaborated on it, so that greenhouses are hardly accounted complete unless they have their batteries of electric lights to make artificial lengthening of daylight possible. But in our admiration of the ingenuity of human gardeners, we must not lose sight of the fact that the first to use this method of bringing flowers into bloom by changing the length of day was the ruler of day itself, the sun.

FRANK THONE
SCIENCE SERVICE

THE SCIENTIFIC MONTHLY

JUNE, 1933

RESEARCH IN THE NATIONAL PARKS

By HORACE M. ALBRIGHT

DIRECTOR, NATIONAL PARK SERVICE

BEING equipped by nature with the most complete and magnificent laboratories imaginable, it was inevitable that scientific research should become an important and popular activity of the National Park Service. Nevertheless, it is one of the newest developments in national park work, which is primarily of a human welfare nature.

National parks began back in 1872, with the establishment of the Yellowstone National Park, the first reservation of its kind to be established anywhere. At the time of its establishment, of course, no thought was given to the scientific aspects of the geysers and other natural phenomena, yet it was because of their presence that the explorers of the Washburn-Langford-Doane party conceived the idea of a national park and gained the support to put this idea through Congress.

The organic act establishing the park provides that the area be "set apart as a public park or pleasure ground for the benefit and enjoyment of the people," and further that regulations be enacted by the Secretary of the Interior "for the preservation from injury or spoliation of all timber, mineral deposits, natural curiosities or wonders within the park, and their retention in their natural condition."

On this foundation has grown up the great national park and monument sys-

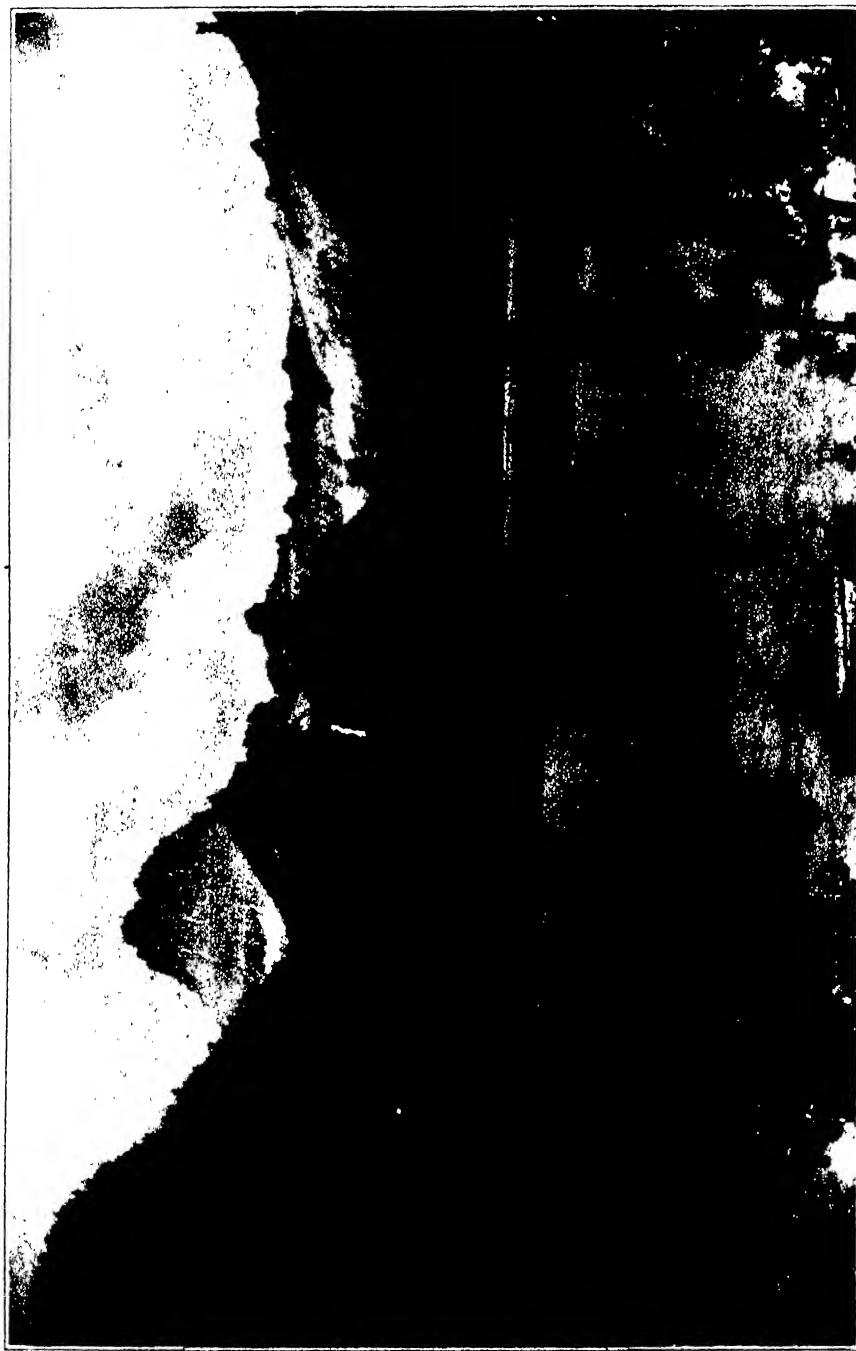
tem that to-day contains 22 national parks and 40 national monuments under the jurisdiction of the National Park Service of the Department of the Interior.

As park after park succeeded the Yellowstone, each was founded upon principles of human welfare, upon the idea of public ownership in and enjoyment of the parks. Yet the underlying motive in establishing each park for the benefit of the people was to preserve something precious from a special standpoint which, when analyzed, proved to be based upon some natural phenomenon or other object of interest to scientists or historians.

Thus the Yosemite, paradise of beauty, also is a geologist's paradise. Some of the Big Trees, to preserve which Sequoia and General Grant National Parks were set aside, were young in the days of the Pharaohs. Mount Rainier, the next to be established as a national park, contains the greatest single peak glacier system in the United States—in addition to exquisite wild flower fields and other features of impressive beauty. So throughout the system.

When the nineteenth century closed, these five national parks constituted the national park system.

The first decade of the twentieth century brought more of Nature's interesting laboratories into the system. There came Crater Lake, a lake of exquisite



T. J. Hileman

SWIFTCURRENT LAKE AND MOUNT WILBUR IN THE GLACIER NATIONAL PARK

blue in the crater of a volcano that collapsed or blew its head to bits sometime in the misty past; Platt, with hot springs possessing healing properties; Wind Cave, with unusual natural decorations and a strangely acting wind which blew in or out, apparently without rhyme or reason; Mesa Verde, ancient home of Basket-maker, cliff dweller, and Pueblo Indians, with a mysterious past that stirs the imagination of the ethnologist and archeologist, as well as that of the average layman; and Glacier National Park, that upturned section of the Rocky Mountains where ancient sedimentary rocks rest upon much younger strata, carved and scarified by great ice sheets and still holding in its mountain fastness the remains of sixty small glaciers.

The same year that Mesa Verde National Park was created Congress broadened the system by passing what is known as the "Antiquities Act." This legislation provided for the establishment, by Presidential proclamation, of national monuments of areas containing objects of historic, prehistoric or scientific interest.

As the national value of these parks and monuments became more apparent, the system grew steadily. The creation of Rocky Mountain National Park, including a typical area of the Rocky Mountains, was followed by two volcanic areas, showing a spectacular form of plastic surgery on the face of Old Mother Nature. One of these, Lassen Volcanic, contains our most recently active volcano on the mainland, and the Hawaii National Park, in addition to its vast dormant crater large enough to hold a modern city, also has two living volcanoes that periodically provide breathtaking displays of great beauty and sublimity.

Another far-away park, Mount McKinley in Alaska, contains the highest mountain on North America, snow-shrouded throughout the year. It af-

fords remarkable opportunities for study of glaciers.

Three superb canyon parks in the Southwest, the Grand Canyon, Zion, and Bryce Canyon, show the wearing, tearing effects of water. Great granite mountains, glacier-laden, are the contribution of the Grand Teton National Park to the system. The huge chambers of Carlsbad Caverns National Park also attest to the dissolving, sculpturing powers of water, and the Hot Springs National Park also owes its place in the system to water--but in this case to medicinal waters, believed, ever since the days of the early Indians, to have definite healing powers.

Formerly a western institution, of recent years the National Park System has moved to the East. The Acadia National Park on the Maine Coast has ancient granite mountains that were old when the West was young; and the Great Smoky Mountains National Park, in addition to its hoary peaks, the highest mountain massing in the East, is famous for the variety and luxuriance of its flora.

The national monuments under the National Park System, established under the authority of the Antiquities Act, cover a wide range of objects. There are fossil plants, petrified trees, and the bones of the long-extinct dinosaur; cliff-dweller ruins and surface pueblos of long-vanished peoples; places connected with the lives of the first white men to settle in America and of early Colonial life; Revolutionary War Shrines; ruined churches erected by the padres who accompanied the gaily adventuring Spanish cavaliers to the New World; a fort built by the serious, patient Mormons—a wealth of areas of such scientific and human interest that their preservation is important to the advancement of our national culture.

Naturally, when the system was young, its first needs, like those of the young



—Colorado Association

CLIFF PALACE IN THE MESA VERDE NATIONAL PARK

human, were protection and proper direction--or administration in the case of the parks. Protective or police organizations were first needed, then means to house the protective force and to care for the physical needs of the visiting public, in reality the parks' non-resident owners.

Once these elementary matters were well taken care of, the National Park Service turned to the aesthetic, or "higher educational" side of the parks.

Interpretation of their natural fea-

worded lectures of to-day, as well as the museum service, grew out of this demand of the visitors to know the "why" of the interesting phenomena--although most of them do not call it that--encountered along the way.

Museum work, in the parks particularly, is quite specialized. The museums are so arrayed as to give the observer a glimpse of the interesting things to be found out in the parks themselves--to interest him to see for himself what the museum suggests. In other



NATURE GUIDE PARTY ON THE TOP OF EAGLE PEAK IN THE YOSEMITE NATIONAL PARK

tures followed. Why geysers "gyze" is perhaps the question asked most in the Yellowstone. In Yosemite, upon seeing Half Dome, visitors want to know what became of the other half--and with the opportunity thus afforded for tactfully imparting a little scientific information, the educational work goes on apace, apparently casually, but always based upon careful research.

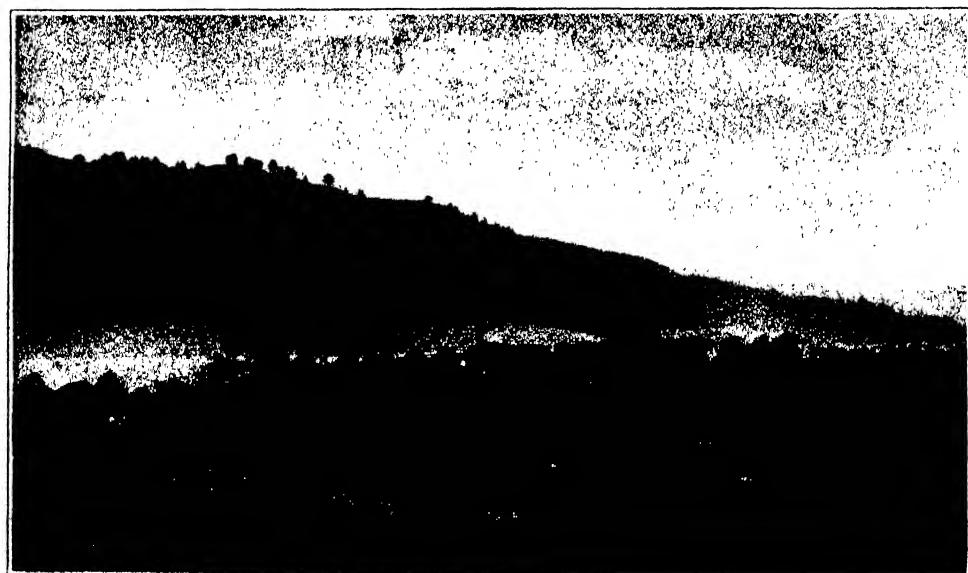
The guided field trips and popularly

words, the museum exhibits are only the indices to the real museum, which is the park.

In the historic and prehistoric members of the system, of course, the museums serve a different purpose. There they actually display relics of human lives--in the former, of our pioneer forbears; in the latter, of a vanished, almost unknown race. A prehistoric burial place yields a skeleton and a few



VIEW DOWN THE GRAND CANYON FROM LIPAN POINT
IN THE GRAND CANYON NATIONAL PARK.

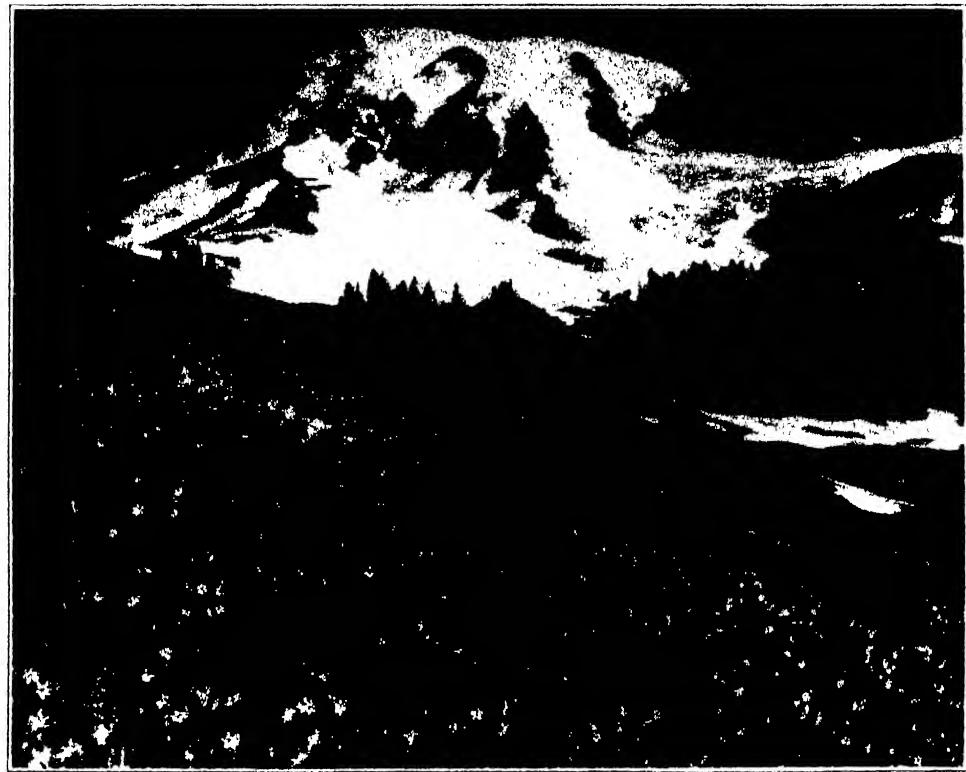


Copyright, J. E. Haynes
A BUFFALO HERD IN LAMAR VALLEY, YELLOWSTONE NATIONAL PARK

trinkets; a plastered-up cache high in a cliff, when opened is found to contain pottery or basketry; here there is a grinding stone and there a weapon of the chase. These all are studied and gradually some idea of the lives of the prehistoric peoples takes shape. This is one of the most fascinating phases of the research work of the National Park Service.

and in the act of August 25, 1916, creating the National Park Service. The latter act contains the following clause:

The service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects



--Ranapar Studio

A BANK OF AVALANCHE LILIES

IN UPPER PARADISE VALLEY IN THE MOUNT RAINIER NATIONAL PARK. ALTHOUGH THE LILIES ARE BLOOMING PROFUSELY, LARGE PATCHES OF SNOW MAY BE SEEN LINGERING BUT A FEW YARDS AWAY

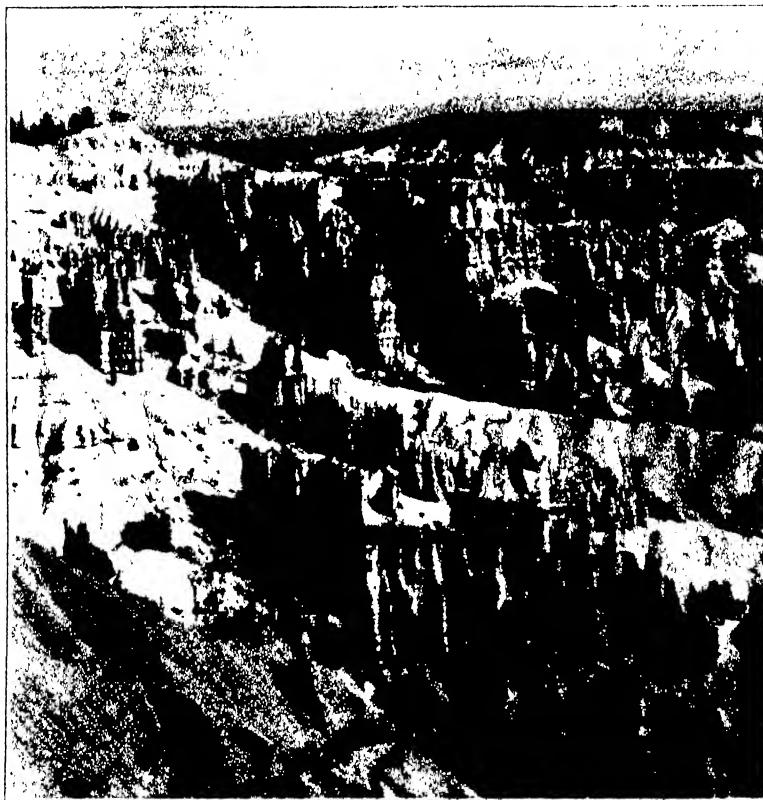
Research is necessary not only to the preparation of interesting material to serve as a basis of the naturalist and historical service, but it also is fundamental to the actual protection of the natural features of the parks, as enjoined in the acts establishing the parks

and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.

There are a great variety of natural objects in the national parks. There are the wild animals, objects of intense in-

terest to visitors, who can not see elsewhere such a wide variety of species and numbers as in these areas, since only in the national parks and national monuments are they given complete protection. The plant life, both tree and wild flower, also makes a tremendous appeal to the average visitor, for one can imagine nothing lovelier than the fields of wild flowers that carpet most of the

Formerly protection of the wild life was primarily a protective function, involving long ski patrols in the winter to afford protection against poachers, both hunters and trappers, and the occasional supplying of food in emergencies. Also in the Yellowstone there has been for a number of years the winter care of the buffalo herd, numbering over a thousand.

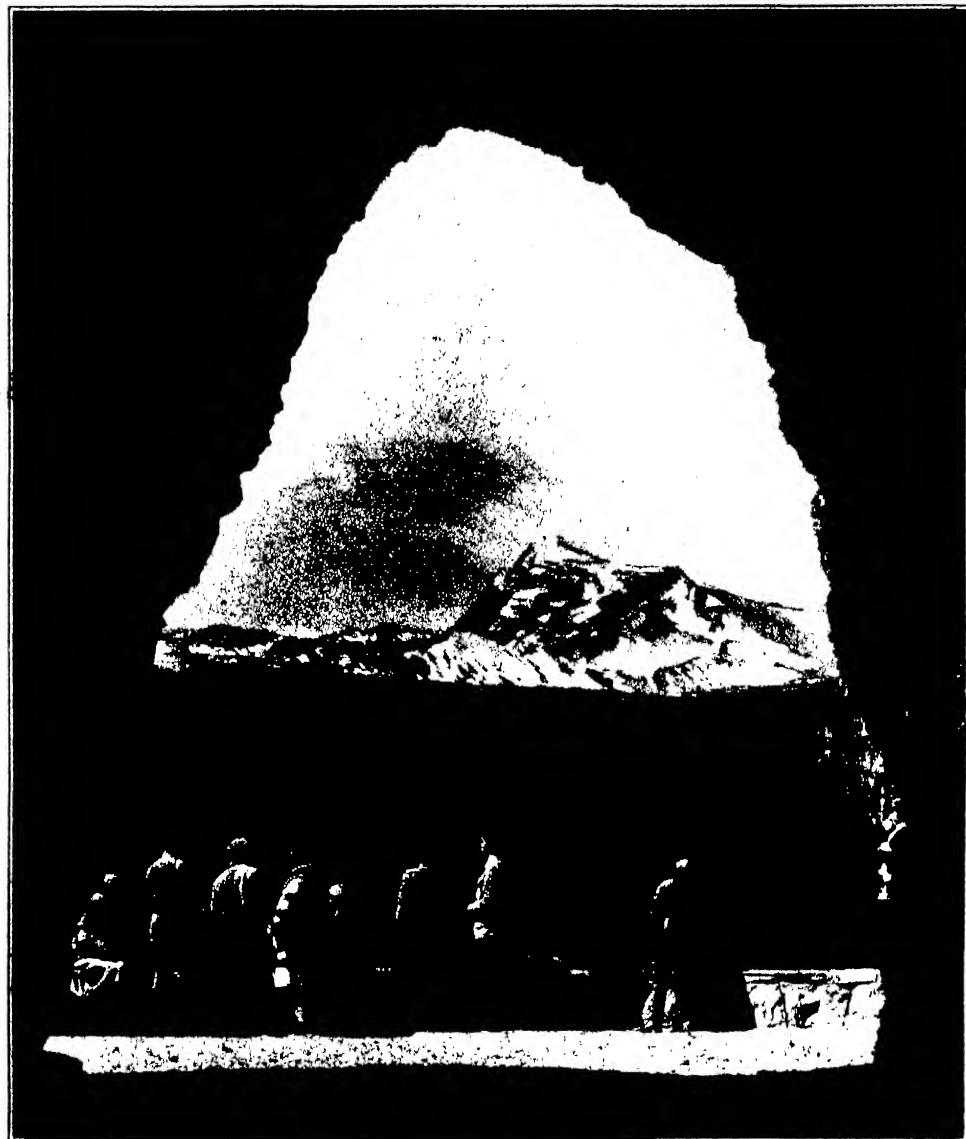


BRYCE CANYON NATIONAL PARK

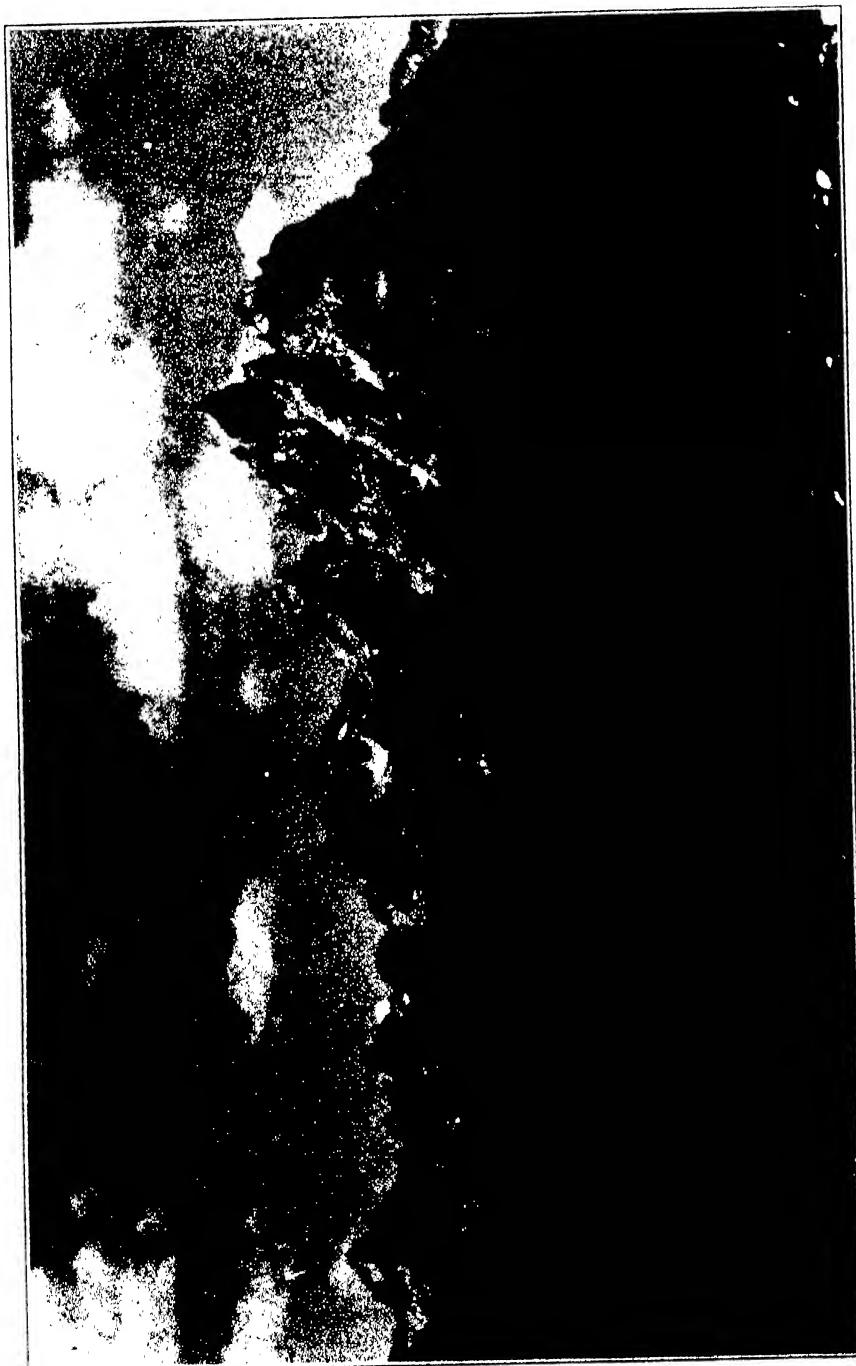
TOURISTS ON THE TRAIL BELOW SUNRISE POINT WITH A PARK RANGER. QUEEN'S GARDEN AND QUEEN'S CASTLE ARE IN THE BACKGROUND. SUNSET POINT IS AT THE LEFT ON THE RIM.

parks during the spring and early summer. Then there are the natural scenic, scientific, and historic features, the main object of the parks' establishment. All of these natural objects need protection, and in many cases research is necessary to determine the cause of some suddenly appearing adverse condition.

Following fundamental protection came the restocking of certain depleted natural ranges. Before going farther with this particular subject, it is important to emphasize that the policy of the National Park Service is unalterably against the introduction of exotic species of animals or plants in the national



-T. J. Haleman
TOURISTS AT TUNNEL WINDOW, GLACIER NATIONAL PARK



GRAND TETON NATIONAL PARK
THE TETONS, SOUTH OF GLACIER CANYON, AS SEEN FROM THE OLD ELK GROVONT POST ROAD ABOUT 4 MILES SOUTH OF ELK. LEFT TO
RIGHT: ALPENGLOW, TAGGART CANYON, MOUNT WISTER, MOUNT MICHAUD, SOUTH TETON, MIDDLE TETON, GRAND TETON, TEEWINAT,
MOUNT OWEN, GLACIER CANYON.

parks or national monuments, except for the occasional stocking of an otherwise barren body of water with some species of game fish for the enjoyment of lovers of the Waltonian sport. Whenever animals are introduced, it is to restock a natural range which has become depleted because of some unnatural condition or series of conditions.

Prominent among the restocking experiments are those of the bison more generally called buffalo—in the Yellowstone, and the antelope at the Grand Canyon. Yellowstone National Park, one of the great areas ranged by buffalo in their wild state, suffered from a depletion in the herds of these animals almost to the point of extinction. A few new animals, specially selected from Texas and Montana herds, were introduced into the park, intensive management undertaken, and to-day the bison herd numbers over a thousand and could be much larger were the range sufficient to support a greater number.

In the Grand Canyon an interesting restocking effort with antelope is just passing out of the experimental stage. At one time these plains antelope were plentiful at the Canyon but changing conditions—possibly caused largely by the wide spreads of the descendants of hardy burros left in the Canyon by prospectors lured to other fields—brought about their disappearance from their former range. In 1924, twelve antelope kids, six bucks and six does were taken to the Canyon, fed and kept under close observation for some time, then released on the Tonto Platform, where it was hoped they would thrive and multiply. For several years prospects looked bad for the survival of these antelope, as they did not easily adapt themselves to new conditions and, possibly because of their careful raising by hand, easily became a prey to predatory animals. After five years of fighting against odds, by the end of 1929 the

herd included only nine animals, four of them kids. During the past year conditions have materially improved, however, and there are twenty animals in the herd. Of ten kids born last spring, eight have survived. The outlook now is favorable for the building up of a large herd which it is hoped can be drawn upon a few years hence for the stocking of other natural antelope ranges in the national park and monument system.

Another interesting experiment at the Grand Canyon has been the transportation of deer from the North Rim across to the South Rim. At first these animals were transported across the Canyon by truck over a long detour covering a distance of 240 miles and requiring from twenty-four to thirty hours to make the trip. Later, for several years, young fawns were transported by a combination airplane and truck trip which was made in three hours. Introduction of these animals to the South Rim, and enlargement of the semi-tame herd over a period of five or six years, has been the means of presenting the public with a highly interesting feature of wild life. In addition, this herd has attracted other deer from regions adjacent to the park, thus increasing the herd to an estimated total of 1,200 head.

Of recent years it has become evident that ranger protection and restocking are not sufficient for the complete preservation of the wild animals. While in the parks it is true that the animals live as nearly as possible under primitive conditions, civilization comes close to the park boundaries, modifying the wilderness conditions; the animals wander back and forth across the boundaries, often coming in contact with domesticated animals, and thus meet vastly different conditions to those experienced by their ancestors back in the middle nineteenth century. Because of this, many situations have arisen necessitating scientific study.

Again, to mention the Yellowstone buffalo, an epidemic broke out several years ago which threatened the decimation of the herd. Experts of the Bureau of Animal Industry were called upon and studies made of the disease. It was diagnosed as hemorrhagic septicemia, and the buffalo were vaccinated against it—not an easy task, as any one who has ever seen these enormous animals in stampede will realize. To-day the herd is thriving—so much so that animals have to be given away each year to keep

however, that a management plan of some sort must be inaugurated by the National Park Service, in order to restore and keep the park wild life in its primitive state despite the effects of human influence. This necessitates, first of all, complete investigation.

Realizing the need of this, an outline of wild life studies was prepared and work along this line undertaken in 1929 with funds made available by George M. Wright, who had become interested in the problem while serving with the



"THE WATCHMAN" IN THE ZION NATIONAL PARK

the number of bison in the park down to the number the range can support satisfactorily.

So one study has followed another, to relieve emergency conditions, and in all such cases the National Park Service has received the unstinted cooperation of the Biological Survey and the Bureau of Animal Industry.

It has become increasingly evident,

educational department in Yosemite National Park. Joseph S. Dixon, economic mammalogist and scientist connected with the Museum of Vertebrate Zoology, was persuaded to assist in this work and he, Mr. Wright, and Ben H. Thompson have carried on the studies with increasing interest and vigor. Since 1931 the National Park Service fortunately has been able to assist in



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RIVERSIDE GEYSER, YELLOWSTONE NATIONAL PARK



TRAILSIDE SHRINE IN YELLOWSTONE NATIONAL PARK

WAYSIDE EXHIBITS ARE LOCATED AT STRATEGIC POINTS AND SERVE AS GUIDES TO THE MOST INTERESTING HISTORICAL AND NATURAL FEATURES OF THE AREA.

financing this work, and during the coming fiscal year will take over practically all the expense.

In their first printed report on the result of their studies, the members of the Wild Life Studies Group report as follows:

. . . throughout the preliminary survey, fixity to the main purpose of obtaining a perspective of the problem in its entirety has been the paramount consideration. Consequently, the search focused on the general trends in the status of animal life, with particular regard to the motivating factors. If a finger can be

placed on the mainsprings of disorder, there is hope of discovering solutions that will be adequate in result. Meeting existing difficulties with superficial cures might be temporarily expedient and, in cases of emergency, necessary, but if continued would build up a costly patch-work that must eventually give out. It would be analogous to placing a catch-basin under a gradually growing leak in a trough and then trying to keep the trough replenished by pouring the water back in. The task mounts constantly and failure is the inevitable outcome. The only hope rests in restoration of the original vessel to wholeness. And so it is with the wild life of the parks. Unless the sources of disruption can be traced and eradicated, the



VIEW OF NORRIS MUSEUM AT YELLOWSTONE NATIONAL PARK

NATIONAL PARK MUSEUMS HOUSE MANY VALUABLE EXHIBITS WHICH SHOW RESEARCH RESULTS.

wild life will ebb away to the level occupied by the fauna of the country at large. Admitting the magnitude of the task, it still seems worth the undertaking, for failure here means failure to maintain a characteristic of the national parks that must continue to exist if they are to preserve their distinguishing attribute. Such failure would be a blow injuring the very heart of the national park system.

One of the most interesting studies undertaken by this group is in connection with the trumpeter swan, one of the birds of present-day America that appears to be fast approaching the end of its journey to join the dodo in the limbo of forgotten things. It has been found

Typical of wild-life research of a co-operative nature has been the study of the Yellowstone elk by William Rush, an investigation initiated by the writer when superintendent of Yellowstone National Park, and later supported jointly by the Forest Service, the Biological Survey, the Montana Fish and Game Commission, and the National Park Service.

Plant life problems, while perhaps not as pressing as those pertaining to the wild animals, are equally important. Forest fires present a constant potential menace to the trees, but improvement



OBSERVING THE WONDERS OF GRAND CANYON

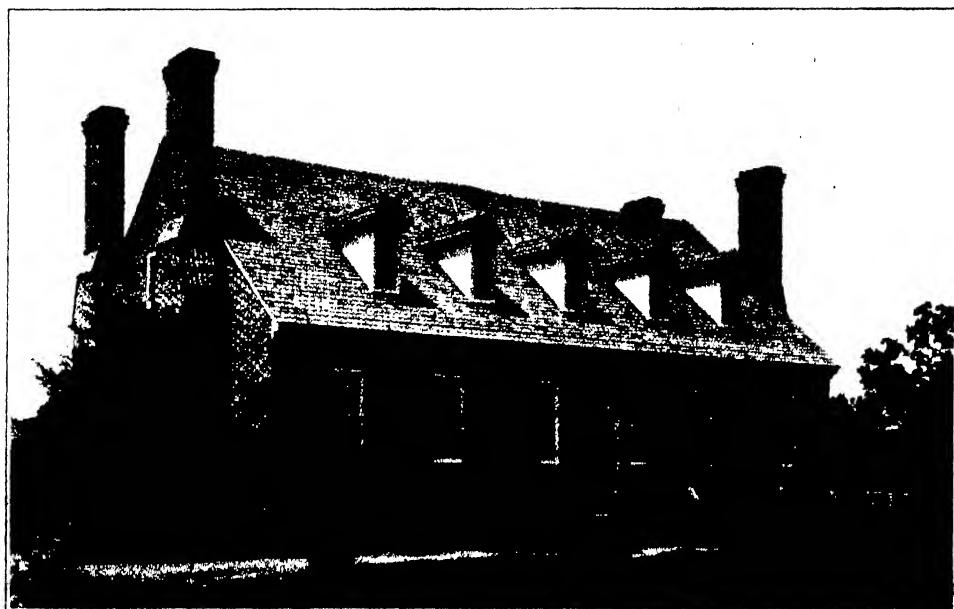
TELESCOPES AT YAVAPAI OBSERVATION STATION AND THE ASSISTANCE OF A RANGER-NATURALIST
AID VISITORS IN THEIR STUDY.

that in the Yellowstone region these birds are making a last stand, and the Wild Life Division, with the cooperation of Yellowstone National Park officials, is bending every effort toward affording the necessary conditions in the park to permit the rehabilitation, if one may call it that, of this magnificent species of bird. Reports now indicate that the possibility is good for giving this species a new lease on life, just as was done in the case of the buffalo.

methods of fire prevention and combat are handling this problem excellently.

Other enemies of park forests are insect infestations and tree diseases. Just as in the case of the wild animals, changing conditions outside park boundaries affect the trees inside. Insect devastations generally start outside the parks, from there encroaching on the trees inside.

Recent surveys show several serious forest situations prevailing in the na-



THE GEORGE WASHINGTON BIRTHPLACE NATIONAL MONUMENT



PROFESSOR ESSIG'S UNIVERSITY OF CALIFORNIA ENTOMOLOGY CLASS AT
THE YOSEMITE MUSEUM

tional parks. One of the worst occurs in the Yellowstone, where the mountain pine beetle threatens the destruction of the lodgepole pine that constitutes about eighty per cent. of the park forest. This epidemic has been carefully studied by experts of the Bureau of Entomology, as well as by Park Service men and officials of the adjoining national forests. It appears that there would be perhaps a fifty-fifty chance of saving these lodgepole pines if a five-year program of control could be undertaken

Canada, and is now coming down into western United States through Washington, Oregon and Idaho. Blister rust control measures have been carried on successfully for several years in Acadia National Park in Maine, and it is believed that by the end of this year the white pine of Acadia will be out of danger through the eradication of host plants. In Mount Rainier Park, in the State of Washington, control measures were inaugurated last year to save a few selected stands of white pine. This work



AN OUTDOOR AMPHITHEATER FOR LECTURE PROGRAMS

HERE, AT OLD FAITHFUL, DAILY TALKS ARE GIVEN BY A RANGER-NATURALIST ON THE SCIENTIFIC FEATURES OF YELLOWSTONE.

immediately, at a probable cost of from \$3,000,000 to \$5,000,000.

This matter was discussed with the Appropriations Committee of the House of Representatives over a year ago. At that time it was decided that such an enormous expenditure was not justified, particularly as there is no definite assurance that even with such appropriations could the ravages of the infestation be stopped.

Another menace to park forests exists in the white-pine blister rust, which first appeared in the East, moved across

will have to be followed up intensively for a year or two, however, if any worthwhile areas of white pine are to survive in that park.

Blister rust is a fungus, its alternate host plants being the currant and gooseberry. It has been discovered that the fungus can move only a small distance from host to pine, but that after reaching the pine it can move a long distance to other host plants. So the method of control is to eliminate the host plants within the necessary radius. Present indications are that in the West control measures can be taken effectively.



LOOKING THROUGH THE TELESCOPE AT SUNRISE LODGE IN MOUNT RAINIER NATIONAL PARK

If this is not done, experts of the Bureau of Plant Industry state that the resultant damage to the five-leaved pine forests of the West will be a national calamity.

A tree problem in Sequoia and Yosemite National Parks was involved in the use of the Big Tree areas by the visiting public. It was found that the constant tramping of feet around several of the oldest and largest of these trees was wearing away and packing down the ground cover to an extent that was threatening the very life of the trees. Careful studies of existing conditions led to the protection of the tree-root areas from encroachment, and the soil, which had been heavily compacted, was brought back to normal by covering the ground with forest litter and the planting of native shrubs. Dr. E. P. Meinecke, general adviser to the National Park Service on matters of forest

pathology, reported recently that the oldest of the Big Trees in Yosemite, the Grizzly Giant "is in decidedly better condition now than it was six years ago. The little branchlets no longer droop as they did a few years ago, but have come back a normal bright green." This means that this old tree, estimated to be about four thousand years old, has been brought back to health, and may watch the generations come and go for a few more thousand years.

So it goes on, through a long list. As one floral or faunal problem is solved, another is presented. And the inorganic features also have their problems, often requiring a great deal of research before a solution is reached. Volcanoes are studied, investigations are made of the geyser fields, where activity in one place ceases, only to break out in another. The effects of glaciers and of running water on granite and other rocks are

given attention by one group of scientists, while another is interested in the formation of great colorful canyons by the effects of wind and rain.

An especially interesting discovery at the Grand Canyon, made possible through the cooperation of the Carnegie Institution of Washington and the National Academy of Sciences, was of fossil plants and the traces of many extinct animals. Both plants and animals dated back to the age of coal plants. In the Algonkian rocks, the strata which represents one of the earliest periods from which remains of life have been obtained, were found fossils of algae, or very low types of plant life.

More than twenty distinct forms of hitherto unknown animals were discovered, not from petrifications or fossilized bones, but merely from footprints made by these creatures in soft, probably moist sands. Some quick covering of the sands hardened and preserved the footprints, to the end that ages later some of them might be unearthed as workmen split the rock in building a new trail, to become part of the educational program at the Grand Canyon National Park.

Increasingly experts of the National Park Service are making studies along various specialized lines, while at the

same time the Service welcomes the many investigations inaugurated and carried through by organizations and individual scientists.

While perhaps not strictly in line with the general trend of this article, which has referred to research primarily from the standpoint of education, some mention should be made of the valuable research being done along landscape and sanitary lines, the former by landscape architects and architects of the National Park Service, and the latter by sanitary engineers of the Public Health Service in cooperation with the Park Service.

Again from the educational standpoint—the incalculable value of the national parks and national monuments as research laboratories has been recognized by a number of schools, including important universities, and many field classes are held therein, particularly in ecology, geology and archeology.

There is no doubt but that this use of the parks as field schools will increase in the future, side by side with the growth in tourist travel. Thus the parks have an important destiny in the future of our national life, from the standpoints of educational, spiritual and recreational values.



A TRUMPETER SWAN AND HER BROOD

THIS SPECIES WAS ALMOST EXTINCT, BUT RECENT INVESTIGATIONS HAVE DEVELOPED BASIC KNOWLEDGE AND NEW METHODS FOR ITS CARE AND PROTECTION. SCENE IN YELLOWSTONE NATIONAL PARK.

THE WORK OF THE NATIONAL BUREAU OF STANDARDS IN METROLOGY AND MECHANICS

By Dr. LYMAN J. BRIGGS
ACTING DIRECTOR

WEIGHTS AND MEASURES

IN a vault at the National Bureau of Standards two pieces of platinum-iridium alloy are preserved with great care because they constitute the basis of the whole system of weights and measures used in the United States. One is the standard of length, the standard meter; the other the standard of mass, the standard kilogram. From the fundamental units of length, mass, and time (the second) all other units used in science and engineering may be derived, with the exception of the unit of difference in temperature.

The Bureau has, in fact, four meter-bars, three of them being used as secondary and working standards. These four bars originally formed part of a large group of standard meter-bars which were constructed by an International Commission in 1889. All of these bars were graduated as nearly identically as possible. After an extended intercomparison, one of the lot was

designated as the International Meter and deposited at Sèvres while the others were distributed to the various nations of the world.

Subsequent comparisons of our standard meter with the international meter were made in 1903 and again in 1923. These comparisons showed that within the limits of accuracy of the measurements the length of our standard meter has remained constant since its original calibration in 1889. Moreover, the length of the international meter has been measured by Michelson and also by Benoit, Fabry and Perot in terms of the wavelength of red cadmium light, so that the meter may properly be said to be well established as a fundamental unit of length.

The meter and the kilogram are fundamental units of the metric system. Inasmuch as the English system of units is largely used in this country, one may properly ask why the system of units should not be based upon a standard



FIG. 1. TAPE TUNNEL
USED IN STANDARDIZING SURVEYOR'S TAPES.

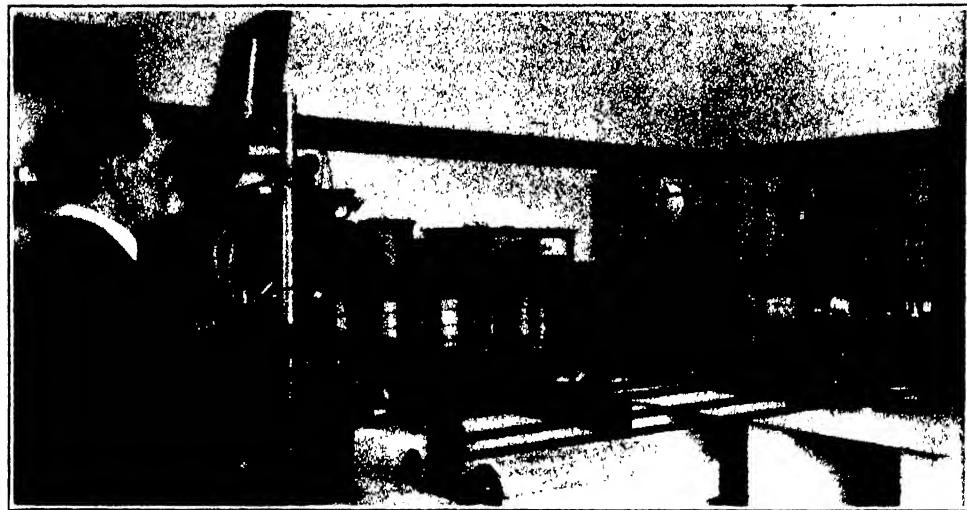


FIG. 2. PRECISION WEIGHING
DISTANT CONTROL OF BALANCE AND WEIGHTS.

yard and a standard pound, instead of the meter and the kilogram.

When Congress legalized the use of the metric system in the United States, it stated that "for practical purposes" one meter is equivalent to 39.37 inches. This ratio made it possible to derive the inch and its multiples from the standard meter, and consequently it is unnecessary to have a fundamental yard standard. Recently, industrialists in this country and in England have asked that the ratio 1 inch = 25.4 millimeters exactly be used in certifying gages for industrial use. This ratio differs from that mentioned above by only 2 parts in 1,000,000, which is of no practical significance. It is of interest to note that the general agreement to adopt this simple commensurate ratio was facilitated through the establishment of European factories for the manufacture of American automobiles.

The constancy of our primary standard of length is not only of fundamental importance in all scientific work, but it is the basis in fact of some of our great modern industries. Mass production of machines such as automobiles is dependent

upon the interchangeability of parts. These machines are literally built up from bins of parts, the parts in each bin being so nearly alike that they can be used interchangeably. Furthermore, the parts are not all manufactured in the same plant, but the ball-bearings may be obtained from one factory, the bushings from another, the gears from a third, the pistons from a fourth, and so on. The housing for the bearing and the axle of the car are finished to such accurate dimensions that on assembly the bearing slips into place without looseness and without strain. Pistons and cylinders, piston-pins and connecting-rod bearings, and other parts that move relative to each other are made with such exactness that they perform smoothly during thousands of miles of driving. How is this remarkable thing accomplished? It is accomplished through untiring attention to standards. The master gages of these various factories are checked with great care against the dimensional standards maintained at the Bureau. These master gages in turn are used in each factory to check the working gages, with which the product

is finally compared. Thus every article used in industry, whose exact dimensions determine in part its commercial value, has been compared directly or indirectly with the length standards maintained at the Bureau. Uncertainty in these fundamental standards of length or any drifting in their assigned values would result in indescribable confusion, delay and economic loss.

Another important application of these fundamental length standards is to be found in the determination of the exact length of the invar tapes used by the Coast and Geodetic Survey in its precise geodetic work. Such measurements are carried out in a special underground tape tunnel suitable for tapes up to fifty meters in length (Fig. 1).

The standardizing of high-class weights probably represents the most precise comparison that is carried out in the Bureau of Standards. In comparing two kilogram weights, the weighings can be carried out, if necessary, with a precision of one part in 100,000,000. Such work must be done in a room where the temperature is practically constant. The observer does not stand close to the balance, but reads the deflection of the balance beam through a telescope eight or ten feet away (Fig. 2), in order that the heat of his body

may not change the relative lengths of the balance arms by a minute amount or set up disturbing air-currents in the balance case. By means of an ingenious mechanism the observer, without approaching the balance, is able to arrest the balance beam, remove the weights, and transfer them to opposite pans.

The other extreme in weighing is to be found in the Bureau's calibration of the master track-scales and test-cars of the railroads. A special car carrying a hundred thousand pounds of weights is used in this work (Fig. 3). When the Bureau of Standards first undertook the work of calibrating railroad track-scales, the tests showed that only three out of every ten scales tested were correct within the permissive tolerances. A marked improvement has accompanied the inspection, and in 1932 eight out of every ten scales tested were found satisfactory.

The calibration of graduated glassware is another important activity of the Weights and Measures Division. This glassware includes such apparatus as volumetric flasks, burettes and pipettes, which are widely used in precise chemical work. All graduated glassware used in analytical work in connection with prosecutions under the Food and Drug Act must be standardized at

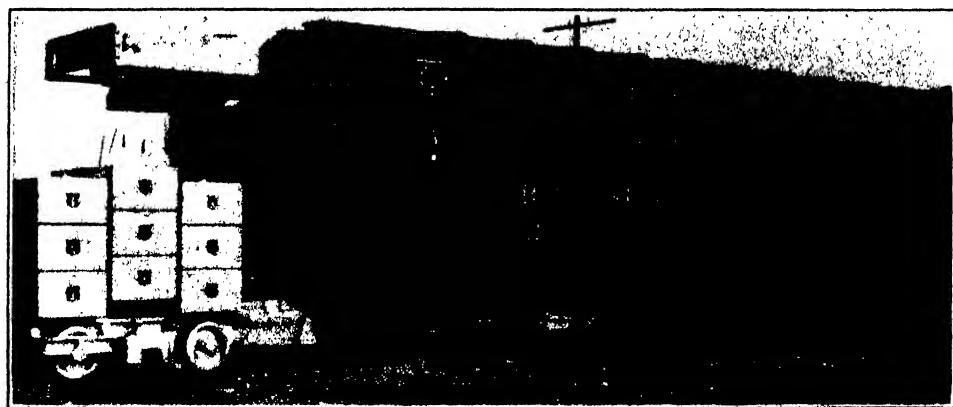


FIG. 3. TESTING RAILROAD TRACK SCALES
EACH LARGE WEIGHT WEIGHS 10,000 POUNDS.

the Bureau, as otherwise the defense will question the accuracy of the analyses. All graduated glassware used by the Customs Service in fixing the revenue derived from sugars and molasses is also tested at the Bureau, as well as most of the glassware used in scientific work throughout the government. Also, vast numbers of dilution pipettes, for use in making blood analyses, are tested for physicians and hospitals and the Veterans Bureau, and numerous hydrometers of various kinds are standardized for the chemical industries.

TESTING ENGINEERING INSTRUMENTS AND MECHANICAL APPLIANCES

Turning now to the work of the Division of Mechanics and Sound, mention must first be made of the great number of engineering instruments and mechanical appliances which are tested annually for various departments of the government and for outside agencies. One of the most important of these instruments is the water current-meter, which is used to measure the volume of flow in rivers and irrigation canals. The essential feature of the current-meter is a tiny propeller which rotates as the water flows past the instrument, while a gear train and an electric contact provide means for counting the number of revolutions of the propeller. Hundreds of these instruments are tested annually for the Geological Survey and the Reclamation Service, and for the Engineer Corps of the Army in connection with its work on the Mississippi River. A special tank four hundred feet long, equipped with a car which travels along the tank at a known speed, is used in calibrating the water current-meters (Fig. 4). The instrument under test is suspended in the water from the car which bridges the tank. The travel indicated by the instrument during a certain time-interval is compared with the distance actually

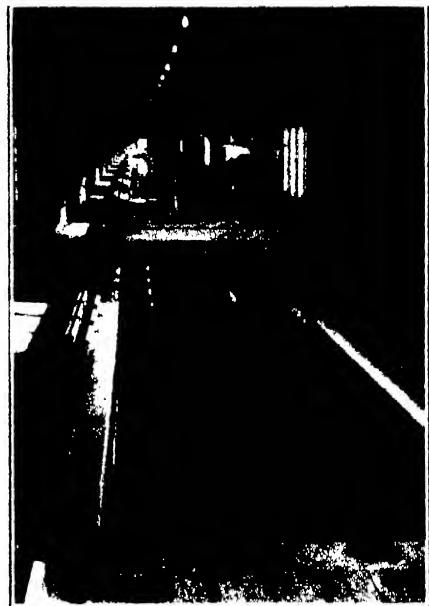


FIG. 4. RATING TANK FOR CURRENT-METERS
TOWING CAR IN FOREGROUND.

travelled by the car during the same time; this gives the correction to be applied to the instrument at that particular speed.

It will be noted that in the process of calibration the current-meter moves forward through still water, while in actual use the meter is held stationary and the stream flows past it. If the flowing stream were free from turbulence this method of calibration would be strictly rigorous, because the motion of the water relative to the meter is all that is required. Actually, the measured stream is more or less turbulent and some correction may be necessary for the turbulence. This question will soon be investigated in the new Hydraulic Laboratory where large volumes of water can be circulated through the great flume, with varying degrees of turbulence. Practically, it is much simpler and far more economical to move the small meter in a long tank of still water than to move great volumes of

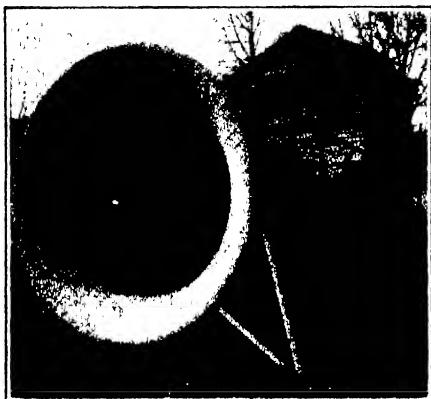


FIG. 5. WIND TUNNEL
ENTRANCE CONE SHOWING HONEYCOMB.

water at a known rate past the stationary meter.

Other tests requiring special equipment include thermostatic valves of various kinds, steam-engine indicators, and pressure gages ranging in capacity from 15 to 5,000 pounds per square inch, or more. Various types of fire extinguishers, including soda-and-acid, foam, carbon dioxide, and carbon tetrachloride extinguishers are tested at the Bureau of Standards before their use is authorized by the Steamboat Inspection Services as acceptable equipment on vessels flying the United States flag. Each lot of extinguishers is held at the Bureau for six months before being tested, because it has been found that some extinguishers deteriorate with time.

Statistics in past years have shown that about three fourths of all fatal elevator accidents result either (1) from opening a door in an elevator shaft when the car is not at that landing, or (2) from starting the car before the elevator door is closed. The United States Government and many states and municipalities now require that elevator doors be equipped with automatic interlocks to prevent such accidents. The success of this measure depends of course upon the reliability of the inter-

lock used. The Bureau has carried out many tests of these devices, one of the requirements being that the interlock shall function 100,000 times in succession without a single failure. During the testing cycle (1) the elevator door is opened, (2) an attempt is made to start the car, (3) the door is closed, and (4) an attempt is made to open the door when the car is (theoretically) away from the landing. All of these operations are carried out by automatic equipment which runs continuously day and night until the test has been completed. It is of interest to note that elevators equipped with interlocks which have successfully passed these tests are granted a much lower insurance rate by casualty companies than elevators not so equipped and protected.

Tests on under-car safeties and buffers (devices to protect elevator passengers in case a hoisting cable should break) are also carried out in cooperation with the American Society of Mechanical Engineers. These tests involve the actual dropping of an elevator (loaded with pig-iron, not passengers) on to the hydraulic buffer under test, which is mounted in the bottom of the elevator pit. Similar tests are made of the under-car safeties, which are designed to grab the guide-rails and stop the car in case its downward velocity exceeds a specified maximum value.

AIRCRAFT INSTRUMENTS

The instrumental equipment of a modern airplane usually includes an altimeter, a tachometer for indicating the speed of the engine, a compass, an airspeed indicator, an artificial horizon, gages for indicating the pressure in the fuel and oil lines, and a thermometer for indicating the oil temperature. All of these instruments should be tested in order that the pilot may have confidence in what they tell him. Work at the Bureau of Standards relating to the testing and development of aeronautic in-

struments is carried out mainly for the Bureau of Aeronautics of the Navy and for the National Advisory Committee for Aeronautics, with the aid of funds provided by these organizations. The Bureau of Standards has developed a number of special instruments for the Navy, several of which are to be found on the new airship *Macon*. One of the most interesting of these is a new type of air-speed indicator which is suspended 50 feet or more below the ship during flight. The instrument resembles a tiny airship about one foot long and carries in its nose a little propeller, which as it is moved through the air rotates at a speed proportional to the speed of the airship itself. This propeller alternately charges a condenser and discharges it through a galvanometer graduated in knots and located in the control cabin. The deflection of the galvanometer is proportional to the number of discharges per second, that is, proportional to the speed of the airship. Instruments of this kind are tested in a wind tunnel where the wind speed can be definitely measured, and are adjusted so as to indicate accurately the true wind speed.

One may ask why it is necessary to suspend an air-speed instrument so far below the hull of the ship. The answer is that the hull of the airship is so large and displaces so much air as it moves forward that it is practically impossible to find any point on the hull (except at the extreme nose) where the airspeed even approximates the true speed of the ship through the air. It is consequently necessary to lower the air-speed indicator to a point below the hull, where the air is not disturbed by the moving ship.

WIND TUNNEL INVESTIGATIONS

Another section of the Mechanics and Sound Division is devoted to aerodynamics, i.e., to the study of the forces exerted on bodies in motion relative to

the air. The primary tool of the worker in this field is the wind tunnel, a device for creating an artificial wind. It consists essentially of a long tube with a suction fan for producing the wind-stream, in which the model under investigation is supported from a suitable balance and held at rest (Fig. 5). If the air flow is uniform the forces are the same as if the model moved through still air with the same relative speed. The tube is shaped to obtain as uniform a flow as possible, honeycomb cells being used to straighten the flow. Some ripples are, however, always present, especially small ripples produced by the walls of the honeycomb cells, which cause momentary changes of speed of 1 or 2 per cent. Much to the surprise of the wind-tunnel staff it was found that increasing the magnitude of the ripples from 1 per cent. to 2 per cent. of the mean wind speed greatly modified the aerodynamic forces on the model in many cases. The drag of a sphere at a given speed was more than halved, the

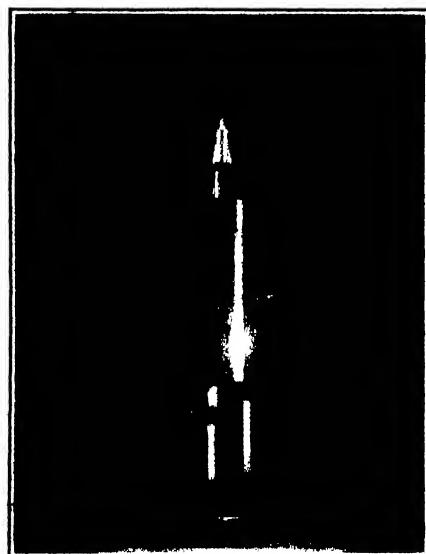


FIG. 6. MODEL OF EMPIRE STATE BUILDING IN WIND TUNNEL THE WIND TUNNEL FAN IN THE BACKGROUND IS FOURTEEN FEET IN DIAMETER.



FIG. 7. TESTING BRICK WALLS
WALLS IN FOREGROUND AWAITING TEST.

rate of rotation of a cup anemometer at a given speed was increased several per cent., the maximum lift of an airplane wing was increased. In order to standardize and compare wind tunnel measurements it was necessary to develop methods for measuring the magnitude of the ripples. This was accomplished by the intermittent cooling effect of the ripples on a heated wire, which changes its electrical resistance. The wire used was less than one thousandth of an inch in diameter, so small as scarcely to be visible under ordinary illumination.

Through wind tunnel studies of models of buildings, the Bureau has contributed to our knowledge of the forces exerted on buildings and other structures in high winds. Papers have been published on the wind loads on a simplified skyscraper model, on a mill building, on chimneys and other cylindrical structures, and recently the results of measurements on a model of the Empire

State Building (Fig. 6) have been described. We hope to be able to compare these last measurements with observations on the actual building.

Another type of aerodynamic study is represented by an investigation of the performance of fans designed after the pattern of an airplane propeller. These fans are particularly suited for circulating large quantities of air against small pressures. Through the work of the Bureau, technical data are available as to the selection of pitch, diameter and best operating speed, and as to the power required to accomplish any specified result.

TESTING FABRICATED STRUCTURES

The load-carrying capacity of a simple column may be computed with a fair degree of certainty if the length and cross-section of the column and the physical properties of the metal are known. But if the column is fabricated from long steel plates and angles held

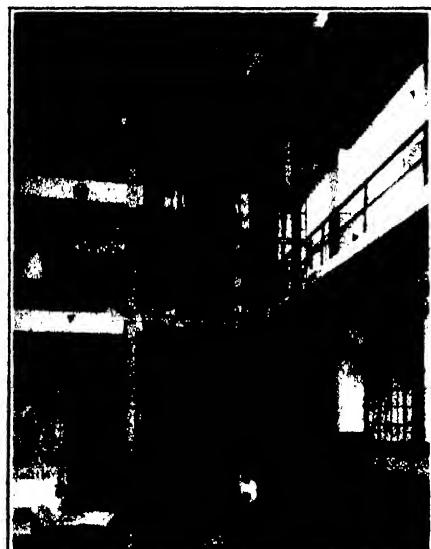


FIG. 8. TESTING BRIDGE COLUMN
LOAD IS APPLIED BY A HYDRAULIC RAM BELOW
THE FLOOR.

together by rivets or welding, the maximum load which it can carry will depend also upon the method of fabrication, and recourse to testing is necessary. Tests are of special importance if the design of any structure departs radically from existing forms or is unusually complex.

The Bureau has exceptional facilities for studying fabricated structures, and has carried out many tests of this kind. Our largest testing machine has a loading capacity of 10,000,000 pounds and can crush a solid brick wall twelve inches thick and six feet long with ease

of a submarine and fitted with pad-eyes were made for the Navy Department, as an aid in determining the practicability of using pad-eyes permanently attached to the hull for raising disabled submarines (Fig. 9).

Many investigations have been made of the strength and rigidity of airship girders, and other structural members of both airships and airplanes. The strength of welded joints of various kinds, such as are used in fabricating the fuselage of an airplane from steel tubing, has been measured. Similar studies have been made of riveted



FIG. 9. TESTING SUBMARINE PAD EYES
CURVED STEEL STRUCTURE REPRESENTS SECTION OF SUBMARINE HULL.

(Fig. 7). But even this great machine was incapable of testing to destruction the giant columns used in the new Washington Bridge over the Hudson, and special experimental columns were made up for testing purposes in which all dimensions were reduced to one half those of the actual column. Even some of these half-scale columns withstood loads of over 9,000,000 pounds (Fig. 8). Other large-scale tests were carried out in connection with the design of the Philadelphia-Camden bridge. Tests of a model representing a part of the hull

joints ranging from the light rivets used in aircraft to the heavy rivets used in joining the plates in the hull of a ship (Fig. 10).

In testing fabricated structures it is important to locate those parts of the structure which are stressed most severely under load, for they must be strengthened if the strength of the structure is to be increased. The stress at any point in the structure is determined by measuring the change in the distance between reference lines or gage marks on the surface of the metal. If a

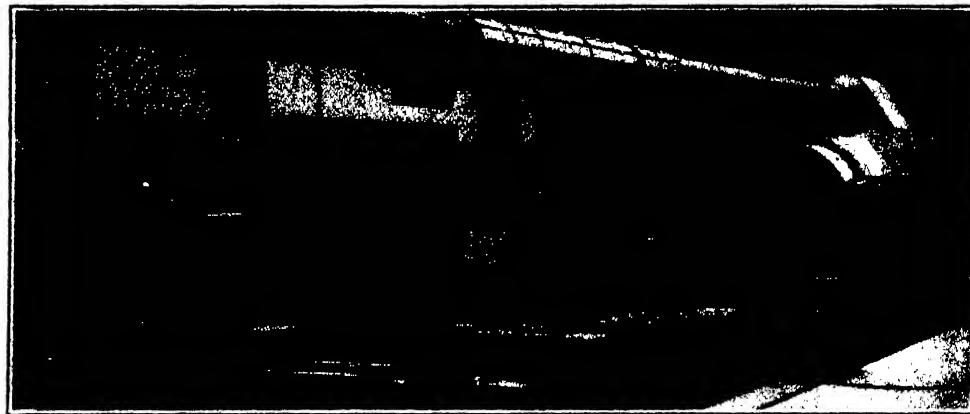


FIG. 10. TESTING RIVETED JOINTS
STRAIN GAGES ARE SHOWN ON THE FACE OF THE STEEL PLATE.

compressive load is applied which does not exceed the elastic limit of the material the gage marks move together by an amount proportional to the load carried by that part of the structure. The Bureau staff has devised some ingenious strain gages for measuring these minute changes in length. The Tuckerman optical strain gage, for example, is capable of measuring a change of two millionths of an inch between gage marks two inches apart. In other words, this instrument will detect the stretch of a steel bar one inch square when it is loaded with a fifty-pound weight.

NATIONAL HYDRAULIC LABORATORY

The new National Hydraulic Laboratory at the Bureau was authorized by Congress because it was believed that substantial savings would result. It has been found in this country, but more particularly abroad, that experiments with a model of a hydraulic structure provide much information regarding the probable behavior of the full-scale structure, and afford a ready means for determining what changes should be made in the original design before the actual construction is undertaken. In fact several different designs may be compared in the hydraulic laboratory at relatively small expense, and the most

effective solution worked out. In the laboratory, the actual structure is represented by a small model made to scale, and the volume of water per second flowing through or around the model is proportionately reduced. Work is now in progress for the Reclamation Service to determine the loss in head resulting from bends in large conduits, and to find the best way of designing the bend to minimize this loss. An effective solution of this problem will save many thousands of dollars annually in pumping charges. Problems concerned with the measurement of water in the field and with the deposit of silt are being undertaken for other branches of the Government. Plumbing systems in high buildings present an unusual hydraulic problem owing to the large volume of air that may be entrapped with the water. It is believed that the hydraulic study of such systems now in progress in the new laboratory will point the way to lower costs and higher efficiency in future designs.

ACOUSTICAL LABORATORY

One of the most recent activities in the field of sound is the development of acoustic tile and acoustic plasters for reducing the reverberation in large auditoriums, cafeterias, banking rooms,

hospitals and office buildings. A smooth hard plaster is a better reflector of sound than a good mirror is of light. Consequently, when a noise is made in a room with hard plaster walls the sound waves generated are thrown back and forth from one wall to another for several seconds. In other words, we continue to hear what a speaker has said, in addition to hearing what he is saying at the moment.

To correct this difficulty, the walls must be made sound-absorbent, and many tiles and acoustic plasters have recently been developed by various manufacturers for this purpose. In fact, this activity has given rise during the years of depression to a new industry. The immediate necessity for such sound-absorbing materials was brought about by the development of sound pictures. Little attention had been paid to the acoustical qualities of moving picture theaters which were originally designed for silent pictures. But with the introduction of the talking picture, it became necessary to correct the acoustical defects in those theaters, and this required the application of sound-absorbing material to portions of the walls and ceilings. Along with this our people seem to have become more sound-conscious, and a wide interest has developed in the reduction of distracting noise, through the use of sound-absorbing material.

In order to be a good absorbent of sound, an acoustic tile or plaster must be porous. The sound wave striking this porous material apparently penetrates it to some extent and in so doing gives up a part of its energy. The

amount of material which must be used in correcting the acoustics of a room depends of course upon the absorption of the material used, which makes it necessary to measure the absorption coefficient of the various sound-absorbents.

The Bureau of Standards has a special laboratory for this work. It consists of a large room with high ceiling and hard-plastered brick walls without windows, and with a single door. Around this room but not touching it at any point except on the common floor slab there is a second similar room, the purpose of which is to protect the inner room from external noises as much as possible. The reverberation of this inner room with its hard walls is truly remarkable. The slamming of the inner door can be heard for 10 seconds or more as the sound waves are reflected back and forth from these hard surfaces with only gradually diminished intensity.

The material to be examined is laid on the floor of the reverberation chamber. Sound of the required intensity and frequency is developed in the room through loud speakers. The source of sound is then suddenly cut off and the rate of decay of the sound energy remaining in the room is measured. This rate of decay together with a knowledge of the characteristics of the empty room suffices to determine the absorption coefficient of the material. A material with a low absorption coefficient is not necessarily less useful on that account. More of it must be used, but in some instances this leads to a better sound distribution.

TRIUMPHS OF EXPERIMENTAL MEDICINE

By Dr. SIMON FLEXNER

DIRECTOR OF THE LABORATORIES, THE ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH

WE are used to being told that we are to-day living in a new world. We are even used to being told, just at the moment, that there is doubt whether the conditions of the new world in which we live are better, indeed may not be worse, than those of the world in which our parents and their parents lived their lives.

However that may be, socially or economically considered, there can, I am confident, be no doubt that our state, medically regarded, is far better to-day than in any previous period of the world's history. This fact, for fact it is, as can readily be shown, requires, I feel, no undue emphasis. There is to-day less illness in relation to the population, with fewer deaths and longer expectation of life, than ever before.

But while all this is true and perhaps quite generally known and appreciated, it is not as generally understood as it should be how these great changes and improvements in health have been brought about, and what greater improvements and benefits may be expected in the next period, if the science of medicine is permitted to continue its progress free from the hampering restrictions and obstructions which certain misguided persons would put in its path.

Suppose, for the sake of comparison, that we imagine ourselves back in the year 1870, which in this country was in the period immediately following the Civil War, during which vast experience was gained in medicine and surgery as understood and practised at that time. These experiences, by no means pleasant to contemplate, are de-

scribed in records and biographies of the hospital surgeons of the time. We shall be transported into a period before bacteriology became a science, and before the amazing discoveries in bacteriology of the Frenchman Pasteur and the German Koch had disclosed the germ nature of wound infection and the contagious diseases, and before the Scotch surgeon Lister, basing his investigations on the discoveries of Pasteur, had introduced antiseptic, soon changed to aseptic, surgery into practise. There are still living a few surgeons who can recall the horrors of those distressing days, when wound infection was rampant, and compare them with the present state of surgical practise, so safe and widely employed that no part of the body, not even the heart and brain, is considered too sacred to be forbidden the exploration of the surgeon's knife. In those earlier days, surgery was limited almost wholly to operations on the surface and extremities of the body; to invade the interior was to invite almost certain disaster; it was to be undertaken only by the boldest and most expert surgeons, and then only when not to operate was even more hazardous than to do so.

All this was changed by the medical research of Pasteur and Lister and Koch in the next quarter of a century. Their investigations, carried out chiefly in the laboratory and at first on animals, provided the scientific foundations for present-day bacteriology and operative surgery, the technique of which has gradually been perfected, extended and taught, until every city and town has the inestimable benefit of the skilled

diagnosis of disease and skilled surgery when needed.

There is no opportunity to deal with details. The knowledge of bacteriology was acquired slowly, and for its acquisition demanded the unremitting labors of very talented men, who succeeded not only through inspiration and effort, but even against much opposition. I have indicated that the discoveries in bacteriology provided the explanation of the sources of wound infection and thus led to the perfection of surgical, operative technique. These discoveries also led to the explanation of the nature of the common infectious and contagious diseases. Just as wound infection results from the presence of one class of bacteria at the site of operation, so do the infectious and contagious diseases result from the presence of particular bacteria within the body.

Those were great days in the last decades of the nineteenth century, which brought to light and opened to experimental study the bacteria producing tuberculosis, typhoid fever, diphtheria and epidemic meningitis, to mention a few notable examples only, and led to the fundamental discoveries in immunity to disease. From the knowledge resulting from these laboratory discoveries we can date those improvements in public health administration which have had so potent an influence in reducing the number of cases and the fatalities of such common infectious diseases as those already enumerated; and, as by-products (and notwithstanding the fact that their germ causes were revealed twenty or more years later) of measles, scarlet fever and other contagious diseases of childhood.

There is great temptation to introduce figures into this story; but time forbids. I must, however, mention one startling change in the prevalence of a disease formerly so destructive among children.

In 1894, before the use of diphtheria antitoxin was introduced, there died in New York City of this disease 4,530 persons, which is at the rate of 163 per 100,000 of population. In contrast to these figures are to be placed those of the year 1932, just passed. In that year there were 212 deaths from diphtheria, or 3 per 100,000 of population.

These are triumphs indeed, the effects of which may be read on every hand in the tables of mortality among infants, children and adolescents, and which in a period of time not too long deferred have led to an increase in the individual expectation of life in the culturally advanced countries of at least 12 years. For a time, this progress if not arrested was at least greatly diminished in speed. The reason was that the improvements in the public health which resulted from the amazing discoveries in bacteriology affected chiefly the infectious diseases of early life, and the extent and safety of operative surgery. The effects of these discoveries and the practical health measures based on them were experienced approximately up to the thirty-fifth to the fortieth year of life. The benefits were thus limited, because the diseases of past middle life present another character and are due chiefly to other causes than those of the diseases of earlier decades.

Just now, and after an interval in which the science of physiology had first to be further built up—precisely as the science of bacteriology had to be developed in the earlier years—progress in the control of disease has been resumed. In this intervening period, physiologists have disclosed the function, or mode of action, of a group of glands of the body, called “ductless” because of their anatomical structure, which had remained enigmas for hundreds of years. The normal action of these glands is essential to the maintenance of health, and

their derangement is responsible, as we have now learned, for serious and fatal diseases as age advances. It is because of the discoveries regarding the nature of the thyroid, adrenal and pituitary glands, and of certain secondary but similar, essential activities of such organs as the pancreas and liver, that increased control is being achieved of certain diseases of past middle life, among which diabetes and pernicious anemia may be singled out for mention. We are in the beginning stages of this advance at the present time; progress is almost continuous at the moment; a bright hope has, therefore, awakened in the hearts of informed physicians and laboratory investigators that the next years will witness a still greater acceleration of the control of chronic disease, compared to which the progress already made, considerable as it is, will appear to have been only a beginning.

Here also are triumphs to be converted into still greater achievements, if the growth of science is to continue unimpeded. You will have perceived that I have omitted to mention still other successes of magnitude in regard to the prevention and cure of disease, which result from the discoveries relating to vitamins, light rays and chemical products or drugs, of which much might be related.

And now, what is it that the experimenter in the laboratory does that has yielded so much already to mitigate disease, improve health and lengthen life, and why is the continuation of his work unfettered by injurious restrictions so essential to further progress? The experimenter studies disease on the lower animals whenever possible, and always under controlled and humane conditions. He seeks to discover the nature of the conditions responsible for disease, just as the chemist and physicist seek to discover by experiment the nature of

the phenomena of matter. There are only two ways of learning about things—observation and experiment. For centuries, very learned and gifted men sought to learn about disease from observation alone; the modern medical era which, in spite of its brevity, has triumphed so gloriously over all past eras, has progressed through the employment of the experimental method. By this method, the element of control is introduced into observation; thus it is possible to learn what is happening at any stage of disease and to utilize this knowledge for the understanding and the better management of disease itself.

Great as is the progress of which I have been speaking, there are hard problems immediately ahead to which answers, at least sufficient answers, have not yet been obtained. I have pointed with what I hope is pardonable pride to the decrease in such diseases as tuberculosis, typhoid fever and diphtheria; but what is to be said of cancer, Bright's disease, and diseases of the heart and blood vessels? You all know how seriously prevalent and destructive these diseases are. There is no lack of effort being made to reach a fuller understanding of their nature, origin and control; and I believe that progress is being made. The ultimate goal seems, however, still distant; there is but one way, I submit, to bring that goal within reasonable hope of being reached finally—and that is by continued, unremitting, unobstructed study by the experimental method.

A final word. I seem to have been telling you about disease in man, and I have been. But every essential thing which I have uttered can be applied equally to disease in animals and even in plants. Everywhere in this country are institutions, supported by state or federal funds, in which animal and plant pathology are being studied. The

advances which have so far been made and which are continuing and becoming ever more rapid, have gone hand in hand with the advances made in the study of diseases of human beings. There are no closed compartments in nature into which man, animals and plants can be separately placed. All are related organically and, as we may say, united physiologically and pathologically. A blow struck at experiments to solve disease in man is felt immediately by those who are endeavoring to prevent disease in animals and plants, and *vice versa*. Koch developed tuberculin in the hope that with it he would benefit sufferers from tuberculosis among men; to-day herds are freed of tuberculosis by injecting tuberculin into

cattle to disclose hidden foci of disease. The malign operation of mosquitoes and other biting insects in conveying disease germs is the same in principle in Texas cattle fever, in malaria and yellow fever in man and in virus diseases of plants. No essential biological division exists between man and the lower animals and plants, whether in respect to health or to disease. If, therefore, we would learn, and through learning grow more powerful and effective to prevent and to cure disease, to lengthen life and to increase happiness through security in all its varied forms, then we should endeavor to act dispassionately and wisely in promoting the advance in knowledge which alone can free us still further from the evils of disease.

LAISSEZ FAIRE, OR COOPERATION

By Dr. WILLIAM ALBERT NOYES

EMERITUS PROFESSOR OF CHEMISTRY, UNIVERSITY OF ILLINOIS

JOHN MAYNARD KEYNES has characterized the present world crisis as a crisis of abundance and not one of poverty. Millions of men and women are threatened with starvation because we have too much wheat, too much cotton, too much of many of the necessities and luxuries of life for which we can find no markets. Keynes also said, when addressing the School of the Liberal party in Cambridge nine years ago, referring to unemployment already chronic in England, "Such a condition is absurd."

The truth of his statement for the United States is apparent from a comparison of the value of agricultural and mineral products and the value added to raw materials by manufacture in 1900 with the corresponding values in 1930. The value of the production in the United States in these three items increased from \$121 per capita in 1900 to \$395 per capita in 1930. It is evident that if the people of our country could maintain a reasonably satisfactory standard of living in 1900, it would be possible for them to maintain a much higher standard to-day if the products were properly distributed by giving employment at suitable wages.

It is well known that the industrial revolution of the nineteenth century, which substituted factory manufactures for home products, was developed first on a large scale in England and that she became the wealthiest country in the world. In spite of the vast accumulation of property, however, the industrial development was accompanied by gross injustice to laborers through long hours of work, unsanitary conditions in the factories, child labor, crowding of tenements and in other ways. In England these evils were partially remedied by

organization of the laborers and strikes which compelled the owners of the factories to bargain with the workmen on more equal terms. Some of the more flagrant forms of injustice were also corrected by appropriate legislation.

During the '80s, when the thrift fostered in France by the effort to pay the German indemnity led to a period of stagnation in the German industries, there was much political unrest and a threatened revolution. Bismarck, seeing the signs of the times, adopted a part of the socialist program, introducing accident and invalidity insurance and other provisions for the benefit of the working people. The political unrest quieted down and there were no serious difficulties for many years afterwards.

Beginning about 1900, a second profound change in industry has occurred which has been called the "power revolution." This has caused the displacement of millions of men by machines.

At the peak of production of automobile tires shortly after the war a certain factory in Akron employed 32,000 workmen. During the temporary slump which came two or three years later the factory was shut down and the employees were scattered. When the demand for tires revived the production surpassed the former high level, but only 16,000 men were employed.

In 1900 a man in the bituminous coal mines produced 2.98 tons a day; in 1928, 4.78 tons, an increase of nearly 60 per cent. At the same time the average number of days which each man worked in a week in 1900 was nearly five. In 1928 it was a little less than four.

It is reported that after the slump came in 1930 one of our largest steel plants employed a considerable number

of its men in enlarging the plant and installing more modern machinery. The capacity of the plant has been doubled, but the number of men employed before will produce twice as much steel.

Other illustrations might be multiplied indefinitely, but these are enough to show clearly one of the most fundamental causes of our distress. Starving people must be fed, but we should see clearly that to feed the unemployed is only an emergency palliative and that genuine relief must come from the restoration of employment.

Communists are proclaiming widely that the present crisis is a complete collapse of capitalism and that the only remedy is the communistic principle, "Give to every man in accordance with his needs; expect from every man service in accordance with his ability." Russia has already found that a distribution of products without regard to the character of the service rendered is not satisfactory and the principle has been modified in the direction of a return to capitalism in two fundamental ways. Superior performance is rewarded by higher wages or privileges of various sorts. And some supplies are sold at exorbitant prices by other than the usual government agencies. The system has met with very considerable success, however, and seems to have the enthusiastic support of the masses of the urban population. It is very hard to imagine a similar success in European countries or America with their well-developed industrial systems.

The *laissez-faire* doctrine dominated Europe and America during the nineteenth century. It assumes that under a system of free competition the endeavor of each to serve his own interests will lead to equitable prices and to suitable compensation of employees. It failed in both respects. The growth of gigantic combinations of manufacturers in America led to the passage of the

Sherman anti-trust law, and the relations of employers and laborers were frequently disturbed by strikes.

The "Power Revolution" has combined with other causes, many of which are direct or indirect results of the war, to produce chronic unemployment in England and Germany and now on a very large scale in America. Against such conditions strikes are powerless unless they include all the workers of a given industry and also include workers who might be transferred from the unemployed of other industries. It was partly a realization of this which led to the "general" strike in England a few years ago. Such a strike is, inherently, civil war between the classes of society and if successful would quickly lead to a condition similar to that caused by a rigid blockade. Such a condition of war would not be permitted to continue by any people. There are four possible conclusions of such a war:

The capitalists may win and establish a dictatorship which will enforce, ruthlessly, a continuation of the old conditions. This was done by Fascism in Italy.

The workers may win and establish, even more ruthlessly, a dictatorship in the interest of the proletariat. This happened in Russia.

A compromise may be reached and previous conditions largely maintained with the unemployed fed and clothed by the rest of the people. This has happened in England.

There is a fourth possibility. This is a whole-hearted cooperation between all classes of society which will result in employment for all, not merely at a "living wage" but at a wage which has some reasonable relation to the service rendered by the individual. The statistics given at the beginning of this article demonstrate that such a condition is now entirely possible.

Whether the wages shall be paid by

an employer controlling capital or by the community is a matter of comparative indifference and depends on whether the community or the corporation can or will render the service most effectively and most fairly to all concerned. We seem to be generally agreed that the post office, schools and roads shall be administered by the community. Water, gas and electric power are sometimes furnished by corporations and sometimes by the community. The telegraph is administered by the community in England and railways and telegraph are owned by the communities in nearly all countries of continental Europe. Refined sugar and steel are entirely in the hands of corporations.

If we accept the thesis that a stable civilization can not long survive with a large class of intelligent citizens unemployed, it is evident that we should search carefully for the causes of unemployment and for permanent remedies. Just as it was found that the principle of *laissez-faire* led to great injustice in the factories and that laws against child labor and regulating the conditions of work were necessary, it is very evident that new legislation is now imperatively needed.

The three most obvious causes of unemployment are: Displacement of labor by machines, decrease in the purchasing power of the people and failure of foreign markets.

The decrease in the purchasing power of the public is due to four important causes; the low prices paid for agricultural products, the cost of the transfer of the products from the farmer to the consumer and failure to lower that cost in proportion to prices paid to farmers, the inability of the unemployed to buy articles necessary to maintain ordinary standards of living and the failure of banks and fall in the price of securities which have impoverished millions of people, rich as well as poor.

The low prices for agricultural products are chiefly due to the overproduction of some staple articles, especially wheat, cotton and corn. A farmers' selling strike can have little effect on such a condition. It may be a question whether large stores of wheat or cotton held for an increase in price may not have an adverse rather than a beneficial psychological effect on the market. If the selling strike could be coupled with a refusal to plant wheat or cotton for another crop and by an increased use of corn for feeding stock instead of for direct sale, something might be accomplished.

Tariffs can be of comparatively little value so long as there is a surplus of the product on the world markets and the production in the United States exceeds the home demand. They may occasionally be of service to exclude Mexican beef or Canadian wheat. It should be remembered, however, that such an exclusion interferes with the market for fruit and for manufactured goods. When the New England farmers could not compete with the wheat and corn raised on the fertile land of the West they were compelled to turn their attention to other crops or to abandon farming. Something of the same sort may happen in relation to Canada and Mexico.

In general, the logical remedy is a greater diversity of agricultural products and a careful study of markets to select the more profitable commodities for production. At this point the Department of Agriculture and the agricultural experiment stations should be able to give good advice. These agencies should help the farmers by giving a broad and careful consideration to the varied economic conditions involved.

The cost of the transfer of the products to the consumer may be lessened by cooperative marketing, with fewer intermediate agencies and by lowering the

cost of transportation. The latter problem must be studied with a fair consideration of the interests of the transporting agencies as well as those of the farmers and consumers.

The most obvious and immediately applicable remedy for unemployment is to shorten the hours of labor from eight to six hours a day or from six to five days a week, distributing the work to be done among a larger number of men. In many cases this would require the men to work in shifts to prevent valuable machines from standing idle. Such changes in the hours of labor have been introduced in some industries and some plants. If corporations will not adopt such measures voluntarily, it may become necessary to make them compulsory.

Persons mining bituminous coal work, on the average, only four days a week. In that and probably in some other industries, a very persistent effort should be made to transfer the younger men to some other industry. Such a policy is contrary to the traditions of the labor unions, but here, especially, the principle of *laissez-faire* has lamentably broken down and modern conditions demand a new treatment of the problem.

As an emergency measure, the day or week may be shortened while the present hourly wage is maintained and the weekly wage is decreased. This is probably necessary because employers as well as employees have suffered tremendous losses during the last three years. It should be remembered, however, that because higher wages are paid in America than in any other country and because 90 per cent. of our products are sold at home, any decrease in the weekly wage curtails in a disastrous manner the market for products. As a permanent policy the weekly wage should be maintained or increased. In the long run the use for the maintenance and increase of wages, of some of the capital which has,

hitherto, been used for the expansion of plants, will be profitable for employers. Such a policy is only another step in the direction the world has gone from the time when the 12- or 14-hour day and low wages were common. It is only a few years since the 12-hour day was discontinued in the steel industry.

The displacement of men by machines calls for a different remedy. Machines are evidently introduced to increase the profits of the manufacturer. It would be equitable to require the manufacturer to use a part of the increased profits to pay the wages of the men displaced, for a definite time after they leave the factory. This would give the men an opportunity to find other suitable employment. In Minneapolis the agency administering relief for unemployment makes a psychological study of applicants and endeavors to find work suitable to the applicant's ability. If a manufacturer will continue on shorter hours—*without decrease in the weekly wage*, the men who would be displaced by a machine, the payment of wages to displaced men would not be necessary. Temporary payments to men displaced by machines have been made in a number of cases. Manufacturers who do not see the justice of such payments and who are not willing to undertake them voluntarily might be compelled to make them by law, just as it has been necessary to forbid child labor and enforce restrictions on hours of labor.

It should certainly be possible to prevent, in the future, such an unreasonable number of bank failures as have occurred during recent years. There have been no failures in Canada or England and we should demand of Congress some method for securing the safety of depositors. The statistics seem to indicate that private and state banks are less well supervised and are more subject to undesirable political influences than are the national banks. It is certainly wrong

when the wishes of the depositors of a closed bank are ignored and receivers are appointed by state authorities. Many millions of dollars which should have gone to depositors have gone to receivers who have held political appointments.

During the civil war we were given a safe currency, by requiring any bank which issued bank notes to deposit in the United States treasury government bonds of a value 10 per cent. in excess of the face value of their notes. Sound banks maintain a certain proportion of their assets in the form of liquid securities and close when these assets are reduced to a dangerous point. The necessity for such a provision should be carefully considered by bank examiners, but nothing can take the place of good judgment and absolute honesty on the part of bank officials and intelligent control by the stockholders.

It is estimated that the value of stocks, bonds and securities quoted on the stock market has fallen \$80,000,000,000 since the spectacular break in 1929. Our total expenditure for the world war, including \$10,000,000,000 loaned to our allies, was only \$32,000,000,000. It has been said that the losses were only paper losses and that the real values back of the stocks and bonds remain essentially unchanged. However that may be, millions of our people have been impoverished and the losses have caused a very unjust redistribution of wealth. This is one very important cause of the decrease in the purchasing power of our people.

Several measures are called for to prevent the return of such conditions. The guarantee of the price of wheat during the war carried the market values as high as \$3.50 a bushel. This caused a very unreasonable inflation of farm values and many farmers, instead of using their increased income to pay off their debts, went further into debt to buy more land. Some of these have lost all their property.

In a similar manner, corporations, encouraged by an abnormally expanding market, spent great sums in enlarging their plants without proper consideration of the producing capacity of their competitors. A vast amount of capital is tied up in manufacturing plants now idle and which can not, for many years to come, give a reasonable return on the investment. This state of affairs has been fostered by the Sherman anti-trust law, which has intensified the usual secretiveness of large corporations and prevented the knowledge of the total volume of business in their own line which might have forestalled much wasteful construction. It is claimed that the government "plan" of Soviet Russia would eliminate this sort of waste. It seems rather evident that if we can abandon the idea that manufacturers are engaged in a competitive warfare and can establish relations of cooperation and mutual helpfulness between them a much better plan can be evolved than any which could be provided by the government. When such cooperation is permitted and established, some method should be provided to prevent the exploitation of the public by high prices, or of employees by low wages. Under present conditions such protection of the public could probably be best secured by a flexible tariff administered by a commission of experts instead of by a log-rolling Congress. When such a commission found that any commodity was sold at a price higher than was necessary to provide a reasonable return on the actual capital invested—not on watered stock or stock issued on accumulated surpluses—and a suitable surplus to provide for dividends and wages of laborers in slack times, the tariff should be lowered to secure competition from abroad. Genuine cooperation must be cooperation between capital, labor and the public. Some rather ineffective beginnings for such a commission have already been made. The interests of the public should be con-

sidered as well as those of capital and labor.

We can not expect to build up a large foreign trade without lowering our tariffs. An expert commission, with power to obtain the necessary information from manufacturers, could most wisely determine which schedules might be lowered without serious injury.

Not long ago the International Labor Office made a careful comparison of the wages paid in different countries on the basis of their purchasing power. The results were :

United States	197
England	100
Germany	77
France	58
Italy	43

It seems doubtful whether we could maintain the present high standard of living for American workmen if we were to open our markets to the free competition of foreign goods. A sudden change of our policy would certainly be disastrous.

Many corporations doing business all over the country are incorporated under the laws of Delaware, with a very inadequate supervision of their character. There is a crying need for a Federal incorporation act of such a nature as to enforce suitable protection for investors and for the public. There certainly is no excuse for holding companies of public utilities when they are made a means for increasing the rates paid by consumers of water, gas and electric power and light.

Many buildings have been constructed and plants built on the basis of a comparatively small payment by the stockholders and the issue of mortgage bonds covering 80 per cent. or more of the undertaking. It would be better business for those responsible for the enterprise to furnish at least one half of the capital required. This would prevent placing on bondholders the burden of

many ill-considered investments. Many such bonds are now "Heads I win, tails you lose." Many other provisions for the security of investments are desirable, but these need not be discussed further.

We are all agreed that the unemployed without financial resources must be fed and clothed and that every endeavor should be made to provide employment by public and private construction of a sort that will contribute to the permanent welfare of the people, such as roads, improvement of parks, reforesting, building of tenements for low rentals to take the place of slums in large cities and much needed school buildings. It is worth while to recall, however, those directions in which unemployment has been relieved during the last 20 years and to think how further progress may be secured.

The automobile industry is a product of the last 30 years. When we think of the thousands if not millions of men who have been employed in building automobiles, in repairing and caring for them in garages, in drilling oil wells and in manufacturing gasoline and oil, we can form some idea of this new line of employment which has absorbed many of the men displaced by the "power revolution."

Incidentally, a great source of enjoyment and increase in the variety of life has been opened up for millions of our people. We can see, here, that the advantages of our prosperity have not been confined to the wealthy but have been shared in generous measure by an increasing proportion of our population. While the three-fold production which has occurred during the last 30 years has given very large fortunes to a few, many have been economically benefited by it.

From the statistics available it seems that there were 630,000 pupils in our high schools and secondary schools in 1900 and 3,345,000 in 1928. There were 224,000 students in colleges and universi-

ties in 1900 and 869,000 in 1928. In both cases there was an increase of 300 per cent. During the same period our population increased about 60 per cent. If the number of students in high schools and colleges had increased only 60 per cent. there would have been only 1,360,000 in 1928 instead of 4,214,000. Assuming that one half of the increase consisted of boys and young men, this means that 1,400,000 boys and young men would now be in the class of unemployed instead of being in schools, if the conditions of 1900 still prevailed. This would have increased unemployment by a very substantial amount.

Here, again, we see that the prosperity of the twentieth century has found its way to a large section of our people. Never before in any land has the opportunity for a higher intellectual life been given to such large numbers of young men and women. Both the automobile and our schools demonstrate that if we can find things which the people want and give them employment the American standard of living may be expanded almost indefinitely. Such things must be discovered in slow detail by men and women who have the vision to see them. Two directions for such discovery may be suggested.

There is a possibility of great improvement in our dwellings in heating, ventilation, conditioning and cooling the air and in decoration and furnishing.

The number of well-trained doctors and dentists makes it possible to organize clinics with staffs which can furnish a good grade of service to people who can not afford to pay the high prices which it is necessary for individual physicians and dentists to charge. The physicians and dentists will make a great mistake if they do not seize this opportunity.

During the first half of the nineteenth century boys and girls on the farms began to do productive work by the time they were 10 or 12 and often earlier. Under such conditions large families were an economic asset. This is no longer true in the twentieth century. Some one has suggested a moratorium on babies as a remedy for unemployment. Certainly parents should not allow their families to increase without careful consideration of the conditions under which the children for whom they are responsible must live.

Communism and Marxian socialism look upon the relations between capital and labor as an irrepressible conflict. Such an attitude is as absurd in a democratic country as the attitude of those Frenchmen and Germans who believe that there is such an antagonism in the character of their races that France and Germany must continue to have recurrent wars.

We have many and difficult lessons to learn before we have fair dealing and genuine cooperation between manufacturers of the same kind of goods, between capital and labor, between teachers and students, between the professional classes and their clients and between politicians and the whole people. When such cooperation comes we shall have put the golden rule into practical effect in economic matters and shall still preserve those opportunities for personal initiative and those high ideals for personal service which are indispensable elements in real progress.

Neither capitalism nor communism can succeed without the acceptance of the golden rule and the development of a spirit of hearty cooperation between all classes of society.

THE PRESIDENTS OF THE UNITED STATES

By Dr. RUDOLF PINTNER

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"THINK of the name of a president of the United States." Such was the stimulus in an association test given by the writer to many students. Perhaps the reader will jot down his response to this stimulus in order to compare it later with the results we are going to give.

The association test in psychology is probably one of the earliest of all tests. It has been used in many different ways and for many different purposes. Its most common use is as a free association test in which the subject is given a stimulus word and is asked to respond by the first word that occurs to him. Hundreds of words have been used in this manner and standards have been obtained for adults and children. If a subject gives very uncommon reactions to a large number of words, he is suspected of being abnormal or peculiar in some way or other. Psychiatrists and psycho-analysts use association tests to discover "complexes" and delve into the subconscious. Association tests are used to help in the discovery of guilty knowledge, on the theory that under great emotional stress the common associations between significant words will be somewhat disturbed. And so the associations have been accurately timed to the thousandth of a second; the same list is repeated a day or two later to check up on inconsistencies; the psychogalvanic reaction for each word is taken; voluntary and involuntary movements of the hands are carefully recorded during the test.

Again, we have the restricted association test where the subject is instructed to respond with the first word he thinks of that falls within a certain category,

e.g., an opposite of the stimulus word; a part of the whole represented by the stimulus; a member of the class represented by the stimulus. This type of association test used to be called "a community of ideas" test because it was supposed to show how much alike our ideas are. Various forms of this test have been used in the psychology of advertising, in the exploration of our interests, and so forth.

The interesting thing about the results of all association tests is the similarity of responses made by the subjects. Individuals of similar education, meaning by similar those who have been to high school or college, respond on the whole by very similar words. Certain associations between words form the common currency of thought, despite the peculiar idiosyncrasies of each one of us. We are not so different as we at times would like to believe, in spite of the diverse details of our common environment. What links a certain word to another is due, according to Thorndike, to the habits formed in hearing, reading, speaking and writing. Let us see what are the habitual or common reactions to the stimulus, "Think of a president of the United States."

This stimulus formed one item of an association test given by the writer to many classes of university students since 1925. Let us see which presidents are most frequently mentioned. Will it give us an index of our most important or our most popular presidents? Here are the gross results for 3,186 students. The responses are arranged in order from most frequent to least frequent. The number and percentage for each response is given.

<i>Response</i>	<i>Number</i>	<i>Per cent.</i>
Washington	784	24.5
Wilson	591	18.6
Lincoln	507	15.9
Coolidge	367	11.5
Hoover	331	10.4
Roosevelt	128	4.0
Harding	107	3.4
Grant	72	2.3
Jefferson	52	1.6
McKinley	45	1.4
Adams	42	1.3
Cleveland	29	.9
Taft	28	.9
Garfield	25	.8
Jackson	23	.7
Monroe	20	.6
Madison	9	.3
Harrison	4	.13
Hayes	4	.13
Johnson	3	.09
Pierce	3	.09
Van Buren	3	.09
Polk	2	.06
Buchanan	2	.06
Hamilton	2	.06
Tyler	1	.03
Fillmore	1	.03
Arthur	1	.03
Grand Total	3186	99.85

Every president of the United States, except Taylor, appears in our list. One non-president, Hamilton, attains the unique distinction of obtaining two votes, thus putting him above three presidents who received one vote each and one president who received none (Taylor). No distinction could be made between the two Adams or the two Harrisons. Both pairs received a very small percentage of the responses. Recency in time is seen in the relatively high positions of Roosevelt and Harding, but Taft comes low in the list. Most noticeable are the relatively large percentages for the first five presidents in our list and the relatively small percentages for all those that follow. The first five presidents obtain 81 per cent. of the responses. The first three alone receive 59 per cent. of the responses. More than

half of the responses go to Washington, Wilson and Lincoln. Almost half, or 43 per cent., go to Washington and Wilson.

The names of Washington, Wilson and Lincoln have become associated with "President of the United States" in the minds of educated adults of the present generation much more strongly than the name of any other president; more strongly than the names of the president in office when the associations were made (*i.e.*, Coolidge and Hoover). If the two most common responses had been Washington and Lincoln, the explanation would have seemed obvious and easy, namely, that these are the two most famous of all presidents, and, therefore, are most likely to pop up in our minds when we are called upon to answer suddenly. But with Wilson coming in ahead of Lincoln, this easy explanation will not hold, because most people do not consider Wilson more famous than Lincoln, although some may put him among the first three most important presidents.

Let us now look a little more closely at the effect upon our associations of a president being in office during the time our associations are made. Coolidge was the "reigning" president during the first part of the period when the tests were given, and Hoover during the second part. Obviously, Hoover's position in the list is not to be compared with the rest because he was not yet president. About half of the associations were gathered before he assumed office. From 1925 to 1929, while Coolidge was president, there were 283 out of 1,694 responses for Coolidge, after 1929 only 84 out of 1,492 responses. The number of responses for Hoover after 1929 is 324 out of 1,492. Coolidge has 16.7 per cent. while in office, and then drops abruptly to 5.6 per cent. While Coolidge drops down, Hoover shoots up to 21.7 per cent. "The King is dead. Long live the King." The effect of

holding office, therefore, is to bring the holder well up among the first three presidents on our list, at least temporarily, but not, be it noted, in either case as high as the position of the first President.

The stability of the responses can be studied by an examination of the percentage of responses by years, and also by the cumulative annual percentages from the beginning of the investigation. The yearly percentages are shown in Table I. The years are academic years

TABLE I
PERCENTAGE OF RESPONSES BY YEARS

Year:	1926	1927	1928	1929	1930	1931
Washington	28.8	26.9	28.4	25.2	22.4	19.1
Wilson	21.0	22.4	17.1	16.3	19.9	15.2
Lincoln	16.0	14.8	15.2	18.7	13.8	15.7
Coolidge	14.8	17.7	16.6	12.1	3.3	5.0
Roosevelt	4.8	3.8	3.8	3.2	3.7	4.3
Harding	2.6	2.8	5.7	2.7	3.3	3.5
Grant	3.6	1.1	4.3	1.6	2.8	2.7
Jefferson	1.4	2.0	2.8	0.4	2.0	2.1
Total cases	642	666	211	564	246	857

beginning in September. The year 1926 includes the data collected from September, 1925, to August, 1926, and so for the other years. In this table the percentages fluctuate somewhat from year to year. The total number of cases each year is very uneven. We notice that Washington is unquestionably first each year. Lincoln and Wilson compete for second place from year to year, now one and now the other gaining the advantage. Coolidge remains high until the last two years, when he drops suddenly. Roosevelt and Harding remain fairly steady with a small percentage every year. Grant and Jefferson with very small percentages fluctuate rather markedly from year to year. On the whole, however, the relative constancy of the percentages is the surprising thing.

Table II shows the cumulative percentages for the six years. Here we have the combined effect each year of

TABLE II
YEARLY CUMULATIVE PERCENTAGES

Year:	1926	1927	1928	1929	1930	1931
Washington	28.8	27.8	27.9	27.2	26.7	24.5
Wilson	21.0	21.7	21.1	19.7	19.8	18.6
Lincoln	16.0	15.5	15.4	16.3	16.0	15.9
Coolidge	14.8	16.3	16.3	15.2	13.9	11.5
Roosevelt	4.8	4.3	4.2	3.9	3.9	4.0
Harding	2.6	3.6	3.5	3.3	3.3	3.4
Grant	3.6	1.8	2.2	2.0	2.1	2.3
Jefferson	1.2	1.6	1.8	1.4	1.5	1.6
Total cases	642	1,308	1,519	2,083	2,329	3,186

the total responses made. Washington remains very steady, with a slight falling-off towards the end. Wilson shows an almost continuous slow decline. Lincoln remains quite stable throughout the whole period. Coolidge holds up well because of his initial large number of votes during his term of office, but the decline begins to show towards the end. Roosevelt shows the same type of stability as Lincoln, except that the percentage of votes is much smaller. The remaining three presidents show surprising stability considering the relatively small number of votes upon which the percentages are based.

Educated Americans respond most frequently by thinking or writing "Washington" to the stimulus, "Think of a president of the United States." This response can readily be explained by the forces of habit. From early life they have been accustomed to think, read, speak, hear of Washington as the first president, the most important president, the greatest president and so on. This response occurs with surprising uniformity in about 25 per cent. of cases in any large group. Coming now to the next most common response, namely Wilson, the explanation is not so obvious. In no sense has Wilson been linked up with the presidency of the United States in the same historical fashion as Washington and Lincoln. And yet with the present generation of

university students his name occurs more frequently than that of Lincoln. Do we have here the influence of affective tone? Wilson is, for the present generation, a man with reference to whom each one of us must "take sides." One must be either for him or against him. People still love, venerate, extol him, or else hate, vilify, execrate him. About 20 per cent. of educated adults react in this way. The gradual decline in percentage in Table II from 21 to 18.6 may be an index of the decreasing emotional tone surrounding Wilson. With reference to Lincoln, the same type of explanation would seem to hold, as with Washington. He is one of our most famous presidents, with an assured historical position. Coolidge shows the effect of holding office and losing office.

The last four responses in Tables I and II all show much smaller percentages, but it is interesting to note the stability of all four of these responses. No one could have guessed that these four presidents, Roosevelt, Harding, Grant and Jefferson, would have appeared after our most popular ones. Recency may explain Harding and Roosevelt, but not Grant and Jefferson. And if recency is a factor, where is Taft? Popularity or enthusiastic ac-

claim may still surround Roosevelt, but certainly not Harding. Historical importance is a possible explanation for Jefferson and perhaps for Grant, but certainly not for Harding and probably not for Roosevelt.

It would seem, therefore, that the factors governing our associations to such a stimulus as "Think of a president of the United States" are very diverse. No simple single explanation is possible. Habit or frequent use in the past seems most important, but contemporary happenings (the president in office now) come in to influence us. The emotional tone surrounding a name may have some influence. Recency, in the sense of having been a president in the recent past, seems to have some little influence. Greatness, in the sense that Washington and Lincoln were great, seems of itself, divorced from habit and use, to have little influence, as witness the small percentages for Jefferson and Adams.

Perhaps the most striking thing about our little experiment is the stability of the results. Year after year, in class after class of students, almost the same percentages of responses appear. Individuality or eccentricity of response is rare. Our thoughts move along in an orderly predetermined manner.

SHALL WE MOVE TO THE COUNTRY?

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I

THERE was a time when a man, asked why he lived in a great city, might reply that he did so because in the city he could earn a living. The noise and dirt and rush of the city he freely admitted, but in the end none of these weighed against the higher wages that he got or hoped to get from the mills and stores and offices that swell the city's bulk.

To-day, when so large a proportion of the working populations of all great cities are unemployed, the economic argument loses much of its force. Slowly it becomes apparent that some things are even more important than money, important though that may be, and that possibly they may be found more easily in the country or the town than in the city. The city is draining back into the country, where there is still wood in the forests for fuel and where there are gardens that will produce food. It may be for the most part an unwilling involuntary exit, but there are also those, both in the city and outside it, who have been driven by their circumstances to an intelligent casting up of accounts, in the effort to decide after a frank survey of the facts whether the tide ought ever to be reversed and the cities resume their mushroom growth of the last century.

Some of those factors have rarely been taken by the city dweller as of prime importance, and yet they are absolutely essential to life in the city or elsewhere, without which life itself is impossible. They lie at the base of all the studies of the biologist and the medical man. They do not conflict with a normal social appetite, for it must be recognized that men, like all other animals, must live

together if life and the race are to be continued. Nevertheless, it is a question whether, in the case of the great city, this innate social drive has not been stimulated past the point of usefulness.

Reduced to the simplest terms of living, men must still have an adequate amount of air or oxygen, food and water, and in temperate and cold climates some protection against the cold. There are also related conditions, such as the humidity of the air, light, pressure, which includes such widely differing factors as osmotic pressure and wind movement, and the character of the ground under our feet, that must be taken into account. In so far as these requirements are most fully met, existence becomes least precarious for men.

Many of these conditions necessary for life normally shift between extremes. Light, for example, fluctuates from that of a bright noonday in summer to the dark of a moonless midnight, and there is good evidence that such variation is stimulating and desirable. The twenty-four hour Arctic summer day might play only less havoc with our civilization than a continual Arctic night.

On the other hand, there must be certain stabilities. A fairly rigid earth crust, not too frequently shaken by earthquakes, is necessary; and even more important than this is a climate that is not too severe or subject to rapidly repeated changes. Many abnormal elements of an environment can be endured if not too extreme or constant. An occasional bitter snowstorm or heat wave is not of serious damage to the people of the temperate regions.

It is a curious thing that apparently the great cities of the world are located

first by their requirement of a certain favorable climate, and only secondarily and within that range by such factors as natural harbors, railroad centers and the nearness of raw material for manufacturing.

Further, the favorable climates are different for different races. Griffith Taylor, English - Australian - American geographer, lists as twelve typically located cities of the white race, London, New York, Berlin, Chicago, Sydney, Perth, Hobart, Capetown, Johannesburg, Aberdeen, Toronto and Seattle. Seven are in the northern hemisphere and five in the southern, but the climates of all are, in general, similar; they show a rather high humidity and not too severe temperatures, though inclined toward rawness rather than mildness. The colored races, either yellow or black, appear to adapt themselves better to another type of climate, and their great cities, such as Calcutta and Shanghai, have grown up under conditions of greater heat and still higher humidity.

Our own great cities do not rise in severe climates, but the studies of another geographer, Huntington of Yale, show that too great constancy of climate is also undesirable. The much maligned, changeable weather of New England is definitely more stimulating to workers, at least those of the white race, than is the more agreeable climate of our Southern States, or of the Hawaiian Islands. The greatest voluntary effort appears to be put forth following small, not too severe changes in weather; and our big cities have grown up in climates which provide these constant changes. It seems unlikely that even by taking much thought they could have been successfully located elsewhere.

It is a pity that, as if to nullify the natural climate, we tend more and more to control weather conditions within the house to one dead level, and to spend more time in these artificially created

conditions. This tendency is general, but the city man is at once the greatest sinner and the greatest sufferer from the high temperatures and low humidities of the common American practise of house heating.

Humidity is one of the essential factors of life to which little effective attention has been paid. Huntington's studies show that, other conditions being equal, low humidities are definitely harmful.

As proof, he has gathered together information on the death rate in surgical operations in a given city with regard to the humidities at which most deaths occur. Surgeons may be supposed not to operate unless there is hope of the patient's recovery; and post-operative care is presumably as good under one humidity as another. Nevertheless, he has found that in Boston, for example, the highest death rate following operations occurs at 25 per cent relative humidity, when the air is very dry; the death rate is distinctly lower at a relative humidity of 97 per cent, when the air is practically saturated; it is lowest of all at the medium value of 57 per cent.

A study of deaths from non-contagious diseases with relation to the humidities at which they occur is also interesting. In more than a million such cases in the United States in 1912-15, Huntington found that there was a definite tendency toward higher death rates during lower humidities.

II

The matter of climate, whether of his general geographical area or the little climate that he creates in his house, has not yet struck the city man as particularly important to him; the concessions he makes to it are largely unconscious; but experience, often very costly of life, has impressed on him that safe water he must have.

A city water supply that will not cause disease must either be secured

from some territory far removed from human habitation, such as the New York upstate reservoirs, or be freed from the germs of disease by some artificial means. This is expensive, but it is not so expensive as polluted water.

In small cities deep wells serve the purpose, in which case the water has traversed a natural filter that removes disease germs. Water from rivers can be purified by filtration that roughly resembles the natural process. In some cities favorably located near a large lake, as Chicago is, the addition of chemical purifiers may render the water safe, though not necessarily pleasant to the taste. When the chlorine is strong in the tap water, those Chicagoans who can afford it buy bottled spring water.

Nevertheless, in spite of the taste, Chicago water is safe, and the history of its supply is as striking an example of the effect of water upon health as can be found. Before the course of the Chicago River was changed, carrying its sewage-laden water away from, rather than into Lake Michigan for the city to drink, the typhoid death rate per 100,000 of population was nearly 200 annually, while now it is under 1.0. Based on the city's present population, this means the prevention of seventy thousand cases of typhoid fever and seven thousand deaths from this cause annually.

Provision of an adequate supply of safe water for a large city has long since ceased to be a private concern, but has been relegated to the health department, as has also provision for sewage disposal. Sewage may be mixed with a relatively large amount of water and emptied into flowing streams, in which case it is certain to be a nuisance to cities farther down the course; or it may be emptied into the ocean where it will not only be a nuisance to neighboring beaches, but may return on the tide to plague the city from which it came. It is probable that the nuisance and the

fouling of places of recreation is greater than the real harm occasioned. At greater expense, to which the cities are slowly being pushed, sewage may be more satisfactorily reduced by bacteria and oxidation in tanks or filter beds constructed for the purpose.

It must be noted that the sanitary index of the great American cities, which is judged largely from the typhoid rate, is materially superior to the average of rural districts. This problem, partly because it was so acute, has been solved and may be placed to the city's credit.

III

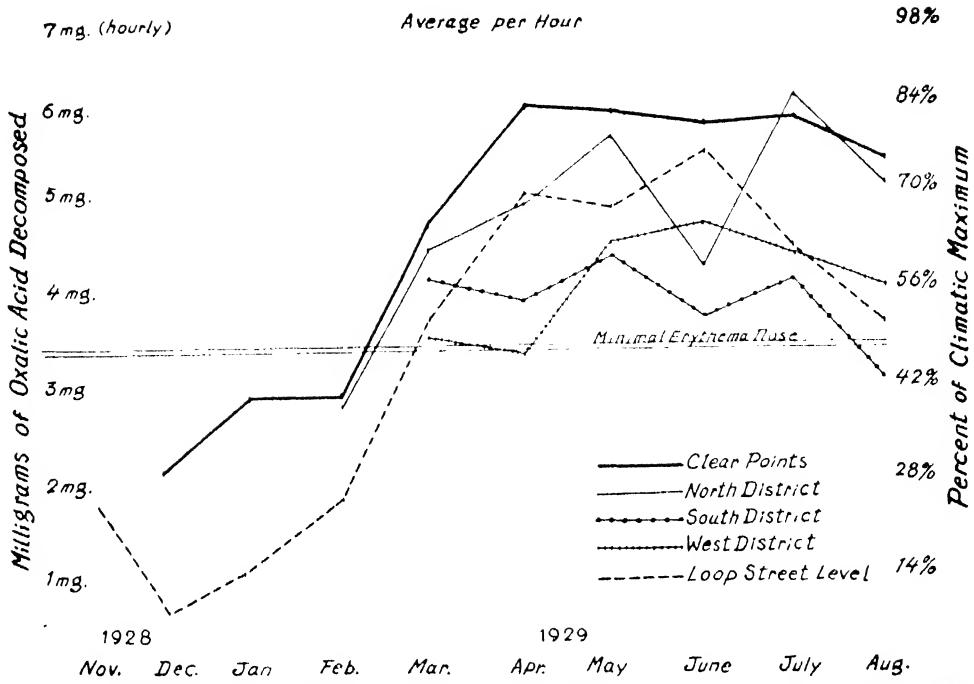
A third essential, good air, is not so easily come by in the city. The city man may breathe and exist, but the coal-black lining of his lungs tells a story of air pollution that passes beyond the stage of mere dirt, for which he may or may not have an esthetic distaste.

Inside and outside of factories and mills the smoke and dust create a problem with which no city has successfully dealt, and even in residential sections of the city where soft coal is burned in furnaces the smoke pall is apparent.

This has its direct effect in increasing respiratory diseases; but there is a more important and undesirable effect of the smoke cloud: on its tiny particles moisture condenses to form fogs, and between the smoke and the fog not only the famous thick choking "London fogs" are formed, but one gray day after another dims the city.

Not only is half the available visible sunlight cut off, so that artificial light must be used, but the effective and useful ultra-violet radiation is also eliminated. Chicago suffers a great loss of these beneficial rays of short wavelength during most of the year; in the winter months no ultra-violet of physiological value reaches the people in its streets.

Other cities show similar effects. Baltimore loses half the amount of



AVERAGE INTENSITIES OF ULTRA-VIOLET RADIATION FOR FOUR CHICAGO DISTRICTS AND FOR ESPECIALLY CLEAR POINTS WITHIN THE CITY. THE DATA WERE COLLECTED IN HOURLY OBSERVATIONS BETWEEN 11 A. M. AND 3 P. M. FOR THE MONTHS AS INDICATED. (FROM TONNEY AND DELONG. 1931.)

ultra-violet which it might receive. Pittsburgh has an especially evil reputation in this regard. In that city an intensive program of smoke abatement has reduced the visible smoke over the city, but has increased the total air dust by 40 per cent. This finer air dust, the result of forced draft combustion, is less opaque to ultra-violet than is the same amount of soot and black tarry smoke, but the increased load which the air carries would seem to offset approximately any advantage gained by more complete combustion, in so far as its penetration by ultra-violet is concerned.

The effect of cutting off health-giving ultra-violet radiation from the city is the more serious since it occurs in the winter months when there is the greatest tendency to stay out of the fresh air, cooped up in the stagnating temperatures and low humidities of city buildings. The whole sum of winter behavior

results in an increase of the death rate, accidents aside, in the winter, as contrasted with the summer and particularly late summer.

But even in the summer Chicago may be seen from an airplane to lie under a vast cloud of gray smoke. This may be alleviated by modern methods of combustion, but it is doubtful if it can be entirely eliminated, even with the best will to do so, while soft coal is consumed. Some cleaner form of heating, probably more expensive, will be necessary before the city child can receive the all-year-round dosage of ultra-violet rays that will insure him good straight bones and high immunity to disease, or the city worker enjoy the greatest health and vigor.

The great number of automobiles on city streets present us not only with our rising quota of accidents, but also with another source of air pollution. It

is a well-known fact, though still overlooked at times, that garage doors must be left open when an automobile is running in order to avoid the deadly effects of exposure to the tasteless, odorless, invisible gas, carbon monoxide. It is not so well known that long exposures to low concentrations of carbon monoxide gas may produce as severe results as shorter exposures to higher concentrations, and that such an exposure may occur in the open air of a street of heavy traffic. In a study of the carbon monoxide content of the blood of fourteen traffic policemen of Philadelphia, six showed a concentration of 20 to 30 per cent., which, while not enough to cause death in an adult, was sufficient to bring on serious symptoms of dizziness, headache and nausea.

In a survey of the distribution of carbon monoxide in Chicago streets, reported in 1928, the samples of air were collected, not at the center of the street, but at the curb, and not at the ground, where the concentration is greatest, but at the level a child would breathe, about three feet from the ground. Under these conditions a concentration along automobile boulevards was found sufficient to be a danger to the health of persons exposed to its action over a period of several hours, with an increased danger to any person who might be muscularly active and hence breathing rapidly and deeply. The air of the lower level of Wacker Drive, a double-decked street fronting on the Chicago River, was found to contain 0.62 parts of carbon monoxide in 10,000 parts air; the streets of the Loop averaged a sixth less and the boulevards slightly less than that. On this evidence the Chicago Department of Health refused permission for the taking of air from the lower level of Wacker Drive for the artificial ventilation of neighboring office buildings.

IV

Fresh vegetables, fruits and other perishable foods are brought into the

city by transportation and refrigeration so good that the city family of moderate means is supplied at all times of the year with a larger variety of food than can be obtained in many rural communities.

Milk, which forms as ideal a food for bacteria as for babies, has been responsible in the past for many outbreaks of typhoid, dysentery, scarlet fever, diphtheria, septic throat and tuberculosis. Health departments have dealt with its difficulties so ably that the city family is assured of at least as wholesome a supply as if it kept a cow.

Commercially canned foods, which form an increasing part of the city diet, are put up under conditions that insure their healthfulness. The raw products going into canned foods are selected at a time when they are thoroughly ripe and are packed under the best conditions and at the temperatures most favorable for the preservation of all the food elements, including the vitamins, many of which are preserved to a greater degree than when the same food is cooked at home in an open kettle with free access of air. There is much less danger of food poisoning from canned food than from uncanned, especially than from warmed-over food.

As with water, superior food is to be had in the city, but at much greater relative expense.

V

The physiological importance of noise is not realized, or the noises that are avoidable would scarcely be tolerated.

An ingenious measuring unit for noise, called the decibel, has been worked out. On this scale zero represents the lack of noise in a specially constructed soundproof room; one represents the sound volume just audible to human ears in such a room; ten represents ten times that amount of noise, as measured by a mechanical device and each succeeding major point on the scale represents the effect of multiplying the preceding value by ten, so that the scale is

NOISE LEVELS OUT OF DOORS DUE TO VARIOUS NOISE SOURCES				
DISTANCE FROM SOURCE	SOURCE OR DESCRIPTION OF NOISE	NOISE LEVEL	SOURCE OR DESCRIPTION OF NOISE	NOISE IN POWERS OF TEN
FEET		DB		
2	HAMMER BLOWS ON STEEL PLATE-SOUND ALMOST PAINFUL (INDOOR TEST)	130 120 110	THRESHOLD OF PAINFUL SOUND (AIRPLANE, MOTOR 1600 R.P.M.; 18 FT FROM PROPELLER) AERO ENGINE UNSILENCED-10 FT.	10^{13} 10^{12} 10^{11}
35	RIVETER	100		10^{10}
15-20	ELEVATED ELECTRIC TRAIN ON OPEN STRUCTURE	90	PNEUMATIC DRILL-10 FT. NOISEIEST SPOT AT NIAGARA FALLS	10^9
15-75	VERY HEAVY STREET TRAFFIC WITH ELEVATED LINE	80	HEAVY TRAFFIC WITH ELEVATED LINE, CHICAGO	10^8
15-50	AVERAGE MOTOR TRUCK		VERY NOISY STREET N.Y. OR CHICAGO	
15-75	BUSY STREET TRAFFIC	70	VERY BUSY TRAFFIC, LONDON	10^7
15-50	AVERAGE AUTOMOBILE			
3	ORDINARY CONVERSATION	60	AVERAGE SHOPPING ST, CHICAGO (BUSY TRAFFIC, LONDON)	10^6
15-300	RATHER QUIET RESIDENTIAL STREET, AFTERNOON			
15-50	QUIET AUTOMOBILE MINIMUM NOISE LEVELS ON STREET:	50	QUIET ST. BEHIND REGENT ST., LONDON	10^5
15-500	NEW YORK {MINIMUM AVERAGE DAY TIME}	40		10^4
50-500	MID NEW YORK] MINIMUM NIGHT	30	QUIET ST, EVENING, NO TRAFFIC SUBURBAN LONDON	10^3
		20	QUIET GARDEN, LONDON AVERAGE WHISPER-4 FT.	10^2
		10	QUIET WHISPER-5 FT RUSTLE OF LEAVES IN GENTLE BREEZE	10^1
		0	THRESHOLD OF HEARING	10^0

made up of successive powers of ten. These powers of ten have been named decibels; 50 decibels represents a noise energy 100,000 times that of the threshold, in mathematical terms 10 raised to the fifth power.

On such a scale a quiet country house has a noise value of 25 decibels; a quiet city street, 50 decibels; a noisy New York or Chicago street is a thousand times noisier than a quiet street, and an airplane engine produces a noise a hundred times greater than that of a noisy city street.

This is more easily realized if translated into human terms. The average street noise of a normally busy New

York street is said by Dr. E. E. Free to make the average person on the street one third deaf; that is, he hears only those tones that a person one third deaf would hear. The noisiest streets render the average person half or even two thirds deaf while he walks among them; the city noises at night cause about one tenth to one twentieth deafness. Any one personally acquainted with the fatigue of partial deafness can translate these statements into still more intimate human values.

In general these city noises are all "necessary" products of our systems of transportation; over 90 per cent. of all the noises at a busy New York corner

were produced by traffic. Trucks accounted for 40 per cent., the elevated railway for 25 per cent., street cars 20 per cent., and, of the remaining 15 per cent., a fair share was produced by private automobiles.

It is interesting to find that a person finds a noise less irritating if he regards it as necessary; the effect varies with the person concerned, and it depends on the pitch as well as the volume of sound; but all noises appear to have some physiological effect.

It requires more nervous energy to do the same work in noisy than in quiet surroundings, even when talking is not required, and if speech is necessary it frequently happens that a very great deal more energy is required. Dr. Laird, of Colgate, has demonstrated that there is an average saving of about 20 per cent. in the energy of typists working in a quiet, as contrasted with a noisy office; and the best typists are those most hindered by noise. For these, moving to a quiet working place would be the equivalent to taking a partial vacation.

Sudden noises affect pulse and breathing and muscular response, and send up the pressure of the blood and the cerebral-spinal fluid; and the effect is greater if the person under observation is already in a state of tension; even the focusing of attention on a picture will increase the response to noise. It is perfectly clear that the continual contacts of city life, the strain of crossing traffic-filled streets, and the assorted worries produced by city competition make relaxation a rare luxury, and provide a tension that increases the harmful effects of noises and other shocks.

Noise abatement engineers can do much toward deadening unnecessary sounds, as the automobile muffler bears witness; they have invented window devices which admit fresh air without allowing street noises to pass, and wall-lining materials which effectively absorb sound inside buildings, but the expense

is so considerable that these are not likely to come into general use very soon.

VI

Despite the cool dark depths of its great buildings the city is hot in summer. Out of doors the masses of brick, stone, cement and asphalt either reflect the heat directly, thus adding to the immediate discomfort of the sun's warmth, or absorb and store it up to radiate it again at night. The city buildings block the free sweep of the night breezes, and the night is only less warm than the day.

In the woods the coolness of the shade is due to the lack of direct sunlight and heat, and it is augmented by the fact that the leaves of the trees are filled with watery sap, so that about a quarter of the summer heat falling on the leaves is dissipated in evaporating sap. In the structurally shaded city there is little or no such protection from the full heat of the sun.

The higher city temperatures are more important from the point of view of health than is indicated by the mere discomfort that they produce. There is strong evidence that infant diarrhea and other intestinal disturbances are increased by high temperatures. It may be that through the hot spells adults are slacker and less carefully clean, but there is good evidence to suggest that the child's difficulty in adjusting to long hot days and nights is a predisposing cause for these particular diseases. The 1918-1920 deaths of children in the United States registration area show that there were almost 50 per cent. more deaths from these diseases among city children than among those in rural regions.

VII

The city dweller is constantly in intimate contact with others, some of whom are suffering from contagious diseases. He is thus exposed in childhood to many diseases with which his country cousin

may not come in contact during a lifetime. Contact with other individuals is the chief method by which diseases are transmitted, rather than by any contact with bedding, clothing, furniture or dust and air. It is well known that individuals, called "carriers," may harbor germs causing such diseases as diphtheria, typhoid and meningitis, though they themselves are not ill. Attempts are constantly and successfully being made to lessen these dangers. More and more we are throwing the responsibility of prophylaxis upon delegated authorities, who administer quarantine regulations, examine school children at frequent intervals, conduct educational campaigns and, when necessary, give free vaccination, toxin antitoxin, anti-rabies treatment and protective serums. With the complete cooperation of the public several of these diseases could be wiped off the list completely with the knowledge and means at hand.

One of the most important diseases more common in the city than in the country is tuberculosis, though in Illinois, for example, in the last twenty years, the death rate from tuberculosis has decreased more rapidly in the city than in the country districts.

Poverty, and the crowding, poor ventilation and deficient food that go with it in the slums of the great cities, has doubtless accounted for the difference here between city and country. The vital connection between income and tuberculosis death rate is startlingly told in the following table, compiled from German statistics, but equally applicable to other countries in the temperate zone.

Taxable income	Number of persons	Death rate per 100,000
900-1200 marks	71,526	482
900-2000 "	48,855	447
900-3500 "	21,397	274
900-5000 "	8,342	252
Over 5000 "	14,323	120

Tuberculosis has been vigorously combated by cooperating federal, state and municipal organizations, with the result that the death rate from that cause in the United States has been more than cut in half in the last hundred years. Whether the greater poverty of the last three years will cause the curve to rise again it is too early to tell, but if it does the effect will probably appear first in the city.

Pneumonia and diphtheria are usually much more prevalent in cities than in the country, as is enteritis among children; whooping cough takes a lesser toll, probably on account of more careful quarantine. Venereal diseases are said to be much more prevalent in the city, though this is a statement difficult to check from facts. It seems fairly plain that the greater difficulty in finding wholesome amusement in our densely populated areas tends to favor opportunity for venereal contagion.

Rabies is also commoner in the city. It is a disgrace to modern civilization that a disease so readily controlled by the simple device of muzzling dogs when on the street, should still take a high annual toll of life. Man and dog have always been closely associated and the tie is hard to break, regardless of the fact that the city is no place for a dog, whatever it may be for his master. With so many people and dogs in a limited area it is small wonder that dog bites are frequent and rabies not at all rare. In England the effect of enforced muzzling of dogs has been clearly shown. Rabies was entirely extinct in England until some misguided humane society workers succeeded in getting the muzzling laws repealed. Rabies again appeared and increased until the laws were again put into effect, when it again became extinct.

Dogs and cats not only carry rabies, but harbor fleas and other vermin, and fleas carry the plague; parrots transmit psittacosis, and rabbits tularemia. It may well be questioned whether the

enjoyment derived from pets is not overbalanced by the health hazard they introduce. In the country the dog may be a very useful or almost indispensable helper, and the greater freedom that he can enjoy reduces to some extent the health hazard; under the artificial conditions of the city he is likely to go from a forlorn and restricted puppyhood through a short life of distemper and indigestion, and end as a limp heap knocked aside by some passing automobile.

The keen competition characteristic of the city, the struggle to exist and to maintain social or financial position results in a number of abnormal physical conditions. This incessant drive, made more serious by noise, crowding and lack of sufficient sleep, is partly to blame for the increased numbers that show high blood pressure, heart and other degenerative diseases. It also accounts for the greatly increased number of suicides and mental derangements, as well as being a factor in family difficulties of all degrees of seriousness. The cases that are definitely mental have been to some extent provided for; the problem of prevention has hardly been touched.

And to the list of city dangers must be added traffic and industrial accidents, and the industrial hazards of dust and heat and poison, for which a whole new department, that of industrial medicine, has been set up.

There is no question but that the best medical and hospital care may be had in the city, especially in those cases in which cost is no consideration. This fact may paradoxically increase the apparent death rate of the city, since the most serious country cases are often sent to the city hospital for treatment, where they may die and swell the city's mortality records.

It must be said, however, that it is not easy for the newcomer to the city or the person without previous experience in illness to find proper medical care. The

country family usually knows personally or by hearsay all the doctors in a wide neighborhood and can select from among them intelligently. Not so the city dweller. The neighboring doctor, for anything he knows, may be good, bad, indifferent or even a quack; he may charge fees too high for this particular patient, of whose financial ability he knows nothing; or the prospective patient may delay getting the attention he needs because of his fear of bills beyond his ability to pay. If he is without funds he finds it equally difficult to know where to turn for medical advice.

In metropolitan Chicago there are between three and four hundred health agencies, from which the patient may select services. Many of these are overlapping or specialized. Who is to tell the stranger where to turn? The organized medical societies will not give the information for fear of showing favoritism. The health department will refer the inquirer only to charitable organizations.

It is partly for this reason that many seek the great organized clinics, connected with hospitals and medical schools, where they feel a reasonable confidence in receiving good care at a reasonable cost. The increase in such group practise, with a hospital as a center, seems to be the best practical solution of this problem, which is vexing both to the patient and the doctor. It gives an opportunity for the doctor to maintain his initiative and independence, but with consulting aid at hand, and with the least expenditure of time and money on the part of the patient.

VIII

There are certain long-run considerations that should be taken into account in this summing-up. The relation between the density of human population and the human death rate has long attracted attention. A law formulated by an Englishman, Farr, states that the

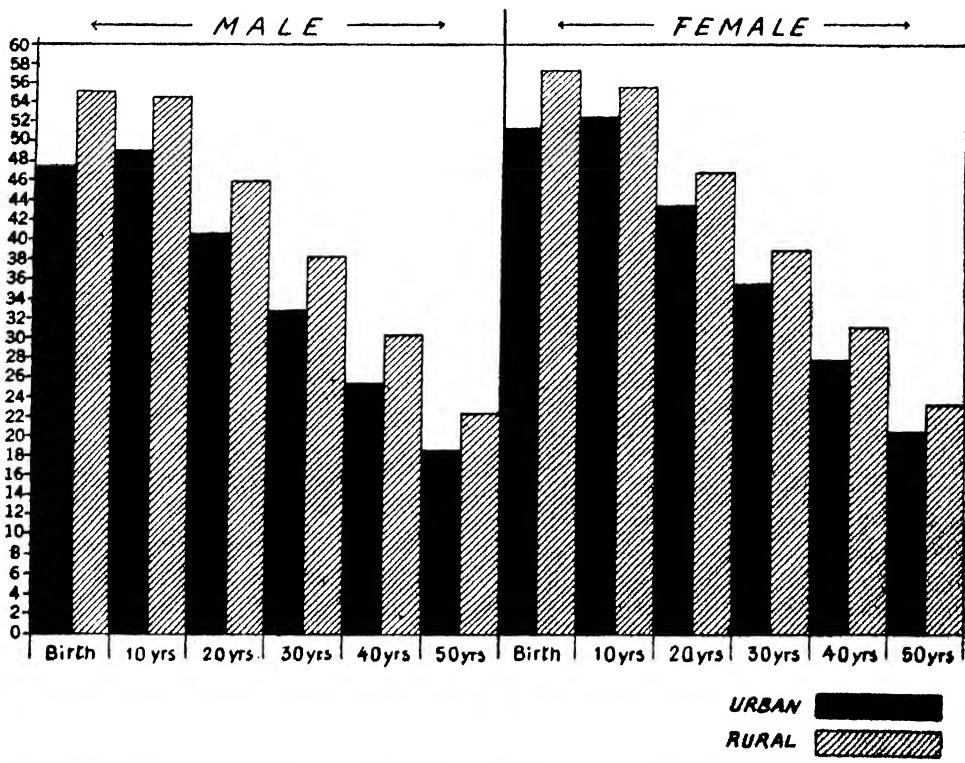
death rate rises directly with the density of population in a given area, when due account is taken of the laws of general sanitation.

This law was first stated for certain regions in England in 1861-70 and was found later to hold for the same regions for the decade of 1891-1900, with the exception that on account of improved sanitary conditions similar densities of population had only about nine tenths of the effect that had been shown in the 1860's. The populations investigated ranged from 166 to 65,823 persons per square mile, which even at the highest is a relatively mild degree of crowding. In the densely crowded districts of New York there are 224,000 persons to the square mile.

The significance of the facts underlying this law may be partially grasped when it is seen that according to United States census figures in the registration of 1910 there were 1,590 deaths per

100,000 population, as compared with 1,390 deaths in rural districts. The corresponding figures for 1920 are 1,411 for urban and 1,194 for rural regions. There is evident improvement in both during the ten years in question, with more rapid improvement in the city districts, but even if the same rate of improvement were to hold for our children's and our grandchildren's generations the country would still show a lower death rate than the city.

The city holds the advantage in infant mortality, and as we have seen, in typhoid and some other contagious diseases, but against this showing must be ranged the fact that in 1920, of the fourteen principal causes of death, not including accidents, only one, typhoid fever, showed a markedly higher rural than urban death rate, and only one other, cerebral hemorrhage, was at all higher in the country. Not even the stream of country patients to city hos-



LIFE EXPECTANCY FOR 1910 IN THE ORIGINAL REGISTRATION AREA OF THE UNITED STATES. (DATA FROM U. S. CENSUS LIFE TABLES).

pitals could wholly account for this difference.

Life expectancy tables, compiled from census figures for the original United States registration area, tell the same story even more strikingly. A boy born in 1911 in the country, and remaining there throughout life, had on the average a right to expect to live 7 years, 9 months and 19 days longer than if he had been born and lived in the city. A young man twenty years old in 1931, born in the city and living in a city thereafter, would at the present time have a life expectancy of some five years less than if he had been country born and bred and remained in the country his whole life. With women and girls there is a shorter spread between city and country life expectancy, but the same general relations hold.

Another interesting consideration in the long run is the apparent effect of the city on child-bearing. The ratio of children under four years to women of child-bearing age (20 to 44) is lowest in cities of a hundred thousand and over. In the United States, for native white women, there are in the larger cities 341 children below four years of age for every thousand women of twenty to forty-four years of age; in smaller cities of two thousand to ten thousand population the number of children rises to 477; and in rural districts as a whole the ratio stands at 721 children per thousand women, which is more than double the city ratio.

Among foreign-born women, whether rural or urban, there is a tendency toward a larger number of children, and the foreign born of recent immigration show a higher ratio than those who migrated earlier; but there is always the same difference between country and city, no matter what the stock.

The effect of city living upon reproduction is most marked among Negroes. In Northern states, where most Negroes are urban, they show a much lower birth rate than the whites of the same

region; in Southern states, where most of the Negroes live in the country, the rate of increase is about as high as that of the native white population.

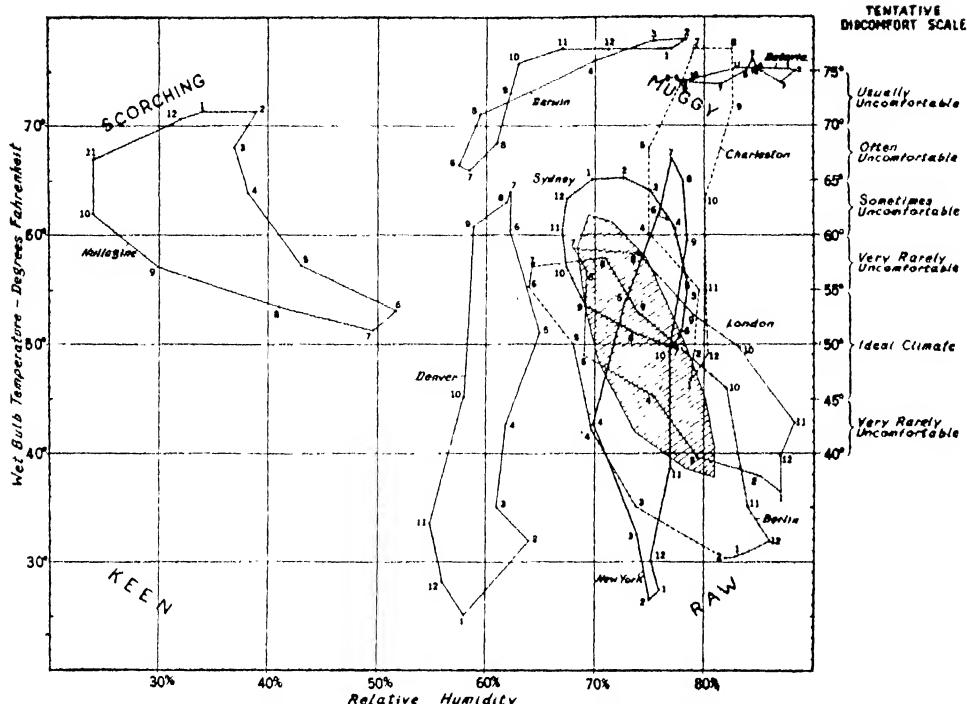
IX

Certain benefits of city living not recorded in the census must in fairness be placed to the city's credit. A foreigner must usually go to the city if he is to find a group of people of his own nationality. In rural regions the newcomer may easily find himself the only Jew or Mexican or Italian in the community, and he may suffer both physically and mentally from his loneliness. In the city he may become a member of a Mexican or Jewish or Italian community, in which he finds partially reproduced the speech and food and traditional customs of his former home, so that the shock of his introduction to a strange world is mercifully lessened.

In the same way cities give opportunity for collections of people of like minds who might be completely isolated in smaller communities. Sculptors, painters, poets and members of the smaller political and religious sects find others of their own kind. Frequently these minority groups are composed of sensitive persons; coming together, the shock of exposure to a critical community is lessened, and greater effort is stimulated by the intelligent appreciation of the group. There is real value in this feeling at home, physiological as well as more intangible.

X

In theory, given sufficient effort and money, it is possible to cancel all the city's deficiencies as a place to live; but we may do well not to expect a rapid change. The application of all our fine knowledge calls for a combination of group unity and expenditure of money on a scale that men have seldom reached. In war time, when victory is desired so fervently that considerations of cost and immediate convenience are overruled,



CLIMATOGRAPHS SHOWING HOW DIFFERENT CITIES ARE DISTRIBUTED WITH REFERENCE TO CLIMATE AS MEASURED BY RELATIVE HUMIDITY AND WET BULB TEMPERATURE. THE SHADED CLIMATOGRAPH SHOWS THE MOIST HABITABLE CLIMATE FOR THE WHITE RACE, BASED ON CLIMATIC CONDITIONS IN THE TWELVE LARGEST CITIES OF THAT RACE, INCLUDING LONDON, PARIS, BERLIN, NEW YORK AND CHICAGO. (MAINLY AFTER GRIFFITH TAYLOR.) NUMBERS 1 TO 12 REFER TO MONTHS OF THE YEAR AND THEIR LOCATION ON THE CHART GIVES THE AVERAGE WET BULB TEMPERATURE AND THE AVERAGE HUMIDITY FOR THE PARTICULAR MONTH. THE CLIMATOGRAPH FOR CHICAGO IS PRACTICALLY THE SAME AS FOR NEW YORK.

large communities or even groups of nations will pour man power and physical resources into a great cooperative effort; but such outbursts of unified action are usually followed by a reaction toward individualism and economy. It does not seem likely that in our time or that of our children we shall see any such general effort to overcome the fundamental handicaps of city living. The cities will muddle along, attacking their problems here and there at their most obvious points, as an epidemic rises to point the moral, or some private organization of public-spirited people brings sufficiently continued pressure to bear on a sore spot.

There is a growing feeling, which the present economic difficulties have accel-

erated, that the best way to solve the city's difficulties is to leave them behind; to move to the suburbs or the country or the small town, where the surroundings are more wholesome and more manageable.

For the great numbers who will remain in the city it is very well that they hold steadily in mind the simple essentials to life that we have just been reviewing: clean air, water and food, full sunlight, warmth, moisture and quiet, and the avoidance of contagious disease; and set an individual and community course toward securing them. If their importance is fully realized there may come a time when a man will not have to give seven years of his life for the privilege of earning a city salary.

UNDER HIS OWN VINE AND FIG TREE

By RALPH E. DANFORTH
WEST BOYLSTON, MASSACHUSETTS

TREES and other plants are almost as much a part of man's natural environment as are sunshine and air and water. He can live longer without food than without air and water, but without sunshine and plants there would be no food. One's *own* vine and fig tree symbolizes two things, the normal environment and an independent supply of necessities. One hundred and twenty years ago relatively more civilized people produced food and clothing on their own land. Mary Lyon, a pioneer in higher education for women and founder of Mt. Holyoke College, with her own hands produced food on a stony hillside farm in northwestern Massachusetts, carded raw wool raised in her native village, spun the wool into thread, wove this into cloth and made her own clothes and bedclothes. Our poet, Whittier, on his native farm in northeastern Massachusetts, produced most of his own food, and in autumn drove his wagon loaded with farm produce, which he exchanged at tidewater on the Merrimack for his winter supply of salt fish brought there on ships from Maine. In my own youth I visited mountain regions in North Carolina, wherein families produced all that they consumed, trading a few items, as wool for sorghum or wheat for beef, with their neighbors, and never happier or healthier people have I seen. They lived under their own vine and fig tree, the fig being replaced by the apple and peach. Of wild grapes they made jelly by the gallon for use the year around, and many apples and peaches were dried in sunshine for constant supply. The home-spun clothing was coarse, but it wore well. Woodchuck skins provided shoe-

strings for shoes, some of which were bought in town.

"But we can not live that way now," say we, "we have forgotten how, and would not want to work so hard if we could."

We pride ourselves that agricultural machinery permits fewer farmers to produce more food, and we leave it to them while we work in office and factory, receiving salary or wage, working for others, yet feeling superior to those dwelling under their own vine and fig tree. We perform marvelous feats to get the exercise and the sunshine we feel we need. Suddenly our industrial organization finds itself overstocked with the numerous wares we help make or distribute, and many wages and salaries are cut down or cut off. However cheap food may then be, it can not be bought without money, and one does not feel very noble receiving either money or food as a gift. Perhaps a small percentage of such folk have imagination enough to think of the vine and fig tree and wonder what has happened to them. For a change they do not feel so superior to those who dwell under their own sources of supply, but console themselves with the thought that there are many in the same state as themselves, and with the added thought that the times will soon improve. "Improvement is just around the corner," people keep saying, but lower and lower drop the wages and fewer grow the names on the payroll. Where is our ability to produce our own fundamental necessities, ability which Mary Lyon and Whittier and a host of our own ancestors had one hundred and

twenty years ago and for ages unnumbered before then?

It is a matter of record that some nine and one half centuries B. C. "Judah and Israel dwelt safely, every man under his vine and under his fig tree, from Dan even to Beersheba, all the days of Solomon." Those days were long looked back to with envy, even though they were days of hard work and much additional forced labor to support the government and carry out its program of construction, all of which was added to the care of individual farms and gardens.

Hard work, drought, pests, crop failures often recurred to disillusion the man with rosy hopes, but the ideal of dwelling under his own source of supplies would not down. More than two hundred years after Solomon's time a prophet arose among his people who, in describing good things for the future, included "they shall sit every man under his vine and under his fig tree; and none shall make them afraid: for the mouth of the Lord of hosts hath spoken it." And two hundred years after this prophet another prophet arose who still painted the the ideal future: "In that day, saith the Lord of hosts, ye shall call every man his neighbor under the vine and under the fig tree." And now, some twenty-nine centuries after Solomon's time, many city-worn men and women feel an urge to the land again; they want to be close to supplies, to live out in the sunshine, to be sheltered by their own living trees, to sow and gather their own herbs and roots, to drink milk of their own cows and water of their own springs and burn wood of their own forest and hear the cackle of their own hens, even though they do not aspire to spin and weave their own clothes as did Mary Lyon and countless others.

But in the northern states climate is hard. The growing season is short. Winter is long and trying to man and to

his live stock. Much food must be stored for man and beast. Barns and storage cost much labor and money. Machinery and modern methods lighten the load even of the northern farmer, making his burden less than that of those who farmed the same lands in earlier generations. More southern latitudes offer more generous rewards in longer growing seasons, larger returns, more sunshine and less storage for winter. Greater variety also can be produced on one spot in milder climates. Less fuel is required. Smaller and less substantial barns are needed. Finally, in a sub-tropical climate, or in the highlands of the tropics, one may literally spend much of the time under his vine and fig tree.

Should the northerner contemplate living in the tropics there will be some who will try to make him afraid. If they tell him that in the tropics it takes work to produce food, they will tell the truth. One of the many absurd myths current about tropics is that there one needs only to reach up and pick his food off a tree at any time. But equally fallacious is the myth that white men can not keep well and efficient in the tropics. Equally untrue is the general notion that tropics consists of either stretches of burning sand, with here and there a clump of palm trees, or else it must be a steaming and impenetrable jungle. There is also the wide-spread notion that even if tropical disease is prevented there still remains something indefinable about the tropics which render it unsuited to civilized man.

It is not my purpose to urge all those who wish productive independence to try the tropics. I simply want to state here that I have personally lived and labored healthfully some years in the tropics and am acquainted with many more who have done so, even at sea-level, although highlands of several

thousand feet above sea offer better temperatures and often better conditions in other ways. The abundant sunshine for man and his crops, and the absolutely all-the-year outdoor climate are the big appeals of the tropics to any who appreciate these two items. It is my own fond hope to again seek the tropics and there work under my own vine and fig tree.

There are limited localities in the tropics where excessive heat, running far above 100 degrees F., are frequent, but I have had no experience with such localities and do not want such. In the more moderate tropics which generally prevail I have spent much time trying to ascertain the cause of the wide-spread belief that white man degenerates in the tropics. I found cases where there was a falling off in efficiency, but more cases where there was little or no falling off, even after many years of unbroken residence, and many cases where there was actual increase of strength and efficiency. In every case where there was diminished efficiency it could be traced to one of three causes: (1) Neglect of well-known precautions against tropical diseases; (2) deliberate departure from moral or temperate life; (3) lack of systematic exercise. This latter is perhaps the least understood of the three causes, for, contrary to the opinion of many, it is just as important to exercise and to exercise hard and systematically in the tropics as in the North. This I found to be the secret of the increase in vigor which some experienced, together with the abounding fresh air at all times and daily sunshine. By avoiding the tropical diseases, which are no worse than many northern diseases, and by avoiding vice and drink, and by taking plenty of exercise every day, in athletic sports, swimming, climbing or in real labor, any one ought to be able to keep in prime condition in any of the ordinary tropical localities. He would do well to avoid

places where temperatures above 100 degrees prevail, or where excessive humidity is the rule. Best of all, let him seek the choicest spots in the highlands. The day will come when the United States will see the wisdom of Great Britain and France in providing themselves with ample realms in the tropics. But it is too late to do this now, and the general public will be blissfully unaware of the lack for some time to come.

Meanwhile, a most wholesome appreciation of the value of outdoor life, of gardens, of sunshine, of birds and flowers and trees is growing up in our midst. A wide variety of vitamin-containing foods come to us all from far and near, fresh as if just picked, and inexpensive at all times of the year. We are fortunate far above our ancestors in many respects. National parks, wild life preserves, bird and flower sanctuaries, open spaces, parks and beauty spots are being set aside and are being appreciated and used increasingly. Boy scouts and girl scouts are entering into a new fellowship with trees and flowers, birds and woodcraft. But this is but a return to the old, time-honored normal way. Through prehistoric ages of unknown antiquity man has lived close to trees, birds, plants and beasts. Earth herself has nourished him, in response to very strenuous efforts on his part, and sunshine, shower and air have conspired to render him tough and sturdy.

Under our rapid industrialization we have, many of us, departed from the normal, shut ourselves behind our new glass windows, excluded the ozone and much of the sunshine, turned our backs on trees and soil and vine and fig tree, and congratulated ourselves that we get money instead of potatoes or grain or apples for our pay, and that with this money we may buy all and whatever we please. Ah yes, quite so! But there seems to come a hitch, even in this well-

oiled system. Somehow industry has its times of drought, its pests, its years of failure. And in times of utmost prosperity its reaction on our physique, and sometimes on our moral life, is not quite all that one could wish.

An eminent professor of law in Duke University has proposed an agricultural army, with semi-military discipline, in which whole families of the unemployed might be kept together and trained to earn their own living from the soil. Large encampments of such people, individuals and families, would be located on large tracts of land in different parts of the United States, and under direction of government experts taught and compelled to produce their necessities. He suggests this as not only better than the dole, but a real cure for unemployment. Too many are ready to say, "we never can go back to producing all we need from the soil." Why not? Under one's own vine and fig tree many a life will be spent happily while life endures on this earth.

For a century there has been a tendency to move certain agricultural activities out of such regions as New England into other parts where greater returns for efforts expended might be had. Some such tendency is noted in other industries also. Summer homes are replacing thousands of New England farms, not only on the seashore but throughout the length and breadth of the region. Old pastures are being replanted with pines. Should this tendency increase sufficiently, the region would be one of summer homes, timber production and of sufficient gardens and dairies to supply the summer folk.

If this same tendency should increase yet more, highlands in the tropics would be utilized for agriculture, manufacture and industry in general, while bleaker, winter-smitten regions become increasingly used for summer resorts and for-

estry. Should aviation become as safe, cheap and common as some predict, travel from tropics to the north and travel around the world would be a commonplace.

Under extended communication the rigors of long winter would be borne only by those seeking winter sports, while every day would be a growing day for the scientific agriculturist and horticulturist, and the manufacturer would forget that he had ever been required to heat a factory or to make it tight and warm against inclement weather. His factory "hands" could have each his own vines and fig and other fruit trees and be happy in the care of them the year around, besides enjoying outdoor air always freely circulating throughout the factory. Should business stagnation again occur, the employees would have spacious orchards, fields and gardens to fall back upon in time of dearth, fields and orchards which could produce something in every season. Doles would not be needed to keep starvation from any door. Perhaps the old prophets were right about every man being happy in the future under his own vine and fig tree.

Too many of our office jobs, shop jobs and diverse employments fail to develop the physical man or woman to full strength and vigor. Our race is in danger of degenerating, as was shown clearly by the physical tests given in selecting those who were to serve in the last war. Nothing can wholly replace systematic, daily, outdoor work.

Fresh air, sunshine and general exercise of the whole body seem to be a daily requirement for every healthy person, a *sine qua non* of real, abiding, heritable health. Some people with a great birth-right of abounding health can seem to do without it, year after year, yet I believe they are consuming their birth-right, and will have less to stand by

them in old age, and certainly less to transmit to their offspring of this abounding health and vigor. Some people can long endure the drain of habit-forming drugs, drink and sex excesses, but the health which they possess is theirs by inheritance, in spite of, not because of the punishment their bodies are undergoing.

Whether born with much health or with little health the expenditure of one's energies in constructive ways, daily, systematically, as much in the open air and sunshine as may be wise, will tend to conserve or even increase the health and vigor we inherited.

The secret of improving the human race lies in passing on to our offspring—not so much better laws, better government, better institutions, more money—as better health, more vigor, brighter minds, larger, deeper, purer souls. This can best be done by the individual himself, rather than by others for society in general. The individual himself or herself can conserve, develop the most desirable traits to transmit to offspring and so combine these with traits in a carefully chosen mate, as to pass on a richer and better inheritance than either mate received alone.

It is said that at the Third International Congress of Eugenics it was shown that American families are sending twice as many children to institutions for feeble-mindedness as to universities. Negative eugenics and legislation may be able to help reverse these figures, and thereby a great good would be done to society in general; and yet the general health and mental and moral status of the better members of society might not be improving in the least, in fact, might be diminishing under indoor life and unnatural practises. The hope for a better race in future lies with the best individuals personally choosing to live normal, health-building lives, free

from all vicious follies, full of constructive virtues, and mating only with those who have more to add to their hereditary values instead of mating with those who may dilute the rich blood stream.

To the all-essential hereditary values passed on to the offspring, should be added environmental values in the form of beautiful surroundings, congenial companions of the highest integrity and ability, health-giving activities, joys and recreation, work and always creative, constructive employment. The creative instinct is strong within the best of people and in some also who are far below the best. This creative instinct may manifest itself in sex activity, either creating offspring or, more often, in wasted although perhaps lawful "expression." One of the most wide-spread errors or mistakes of mankind lies in thinking that any health, beauty or value lies in such waste. Many are even told that manly strength is increased by such activity, or that it is necessary for health or happiness. Neither man nor woman needs any such activity. When expressed in the production of offspring of really superior quality it is one of the finest achievements of mankind. When gratifying a mere desire, or even a companionly impulse, it might far better be supplanted by something more truly constructive and more intrinsically valuable. The poisoned or polluted mind is easily fooled into thinking that the ways of disintegration are good. In all the world of nature, vegetable as well as animal, nothing but dire disease consumes more energy than sex. Many a creature lives, grows, reproduces and therein expends its every ounce of energy and life. Even the longer-lived animals and plants have their times of reproduction sharply restricted, with long intervals of preparation and storing of energy for the important event.

The way in which man has departed from nature and her laws, and thinks himself above law and an exception to the laws of all animate nature, which he considers beneath him and a thing apart from himself, is one of the most crying mistakes to which human judgment is prone.

Fruit trees store up energy in the cells below the bark, gradually preparing for the great ordeal of producing a crop. The wheat plants in the field expend all they have in producing man's staff of life. They die in the act, as do myriads of other creatures. The wild birds go through a long time preparing for their periods of parenthood. Man, on the contrary, cares little how he throws the torch of sacred life. He is superior, he thinks, to all nature, why be governed by its laws. Is not the impelling urge within him sufficient proof that it is wise and right to follow it blindly? Why is not life enriched and beautified by the more self-expression? Expression in what, for what, and to what purpose, may we ask?

The vine and the fig tree have lessons to teach the men who live happily and toil beneath them.

It seems almost a pity that those who would like to choose their own heredity can not do it. Several things can be done, some of which favor the offspring, while others improve only the person doing them. One may choose about half of the heredity of one's offspring. One may avoid great waste of energy through anger, sex and fear. One may steer clear of racial poisons and of many diseases which not only greatly damage self but lower the vitality of the offspring. One may choose, among the many hereditary traits one has received, which ones shall be developed and stimulated and which shall be suppressed or inhibited. One may surround himself

with an environment most favorable for self and for offspring, including associates of the highest order, nutritious food consumed sparingly, comforts of home, ideal location, gardens and trees and scenery. One may fill the mind with beautiful, pure, noble, useful thoughts only and always. These environmental and disciplinary factors will continually improve one's entire personality, including looks, health and happiness. One may fill the heart with a living faith of the kind which works ever for progress.

If horticulture be not one's vocation, it may make a most salubrious avocation. The plant world is nature's primal setting for man and the entire animal world. Nothing could be more wholesome than living and working with forest, orchard and garden. There are fruits to fit every palate and every need. Most of the choice fruits are as yet unknown outside of restricted localities. Some may question this last statement, since most of splendid fruits of the temperate zone are pretty well known in the temperate parts of the globe, and many tropical fruits are known and grown around the tropical belt. Yet there are literally hundreds of choice tropical fruits which have not yet been widely dispersed. And many less choice fruits are capable of great improvement in the future under the care of the horticulturist and plant breeder. A mere list of names of the tropical fruits already desirable would astound the average person, even in the tropics.

Our first and most versatile president pronounced agriculture the most delightful and useful occupation. He was horticulturist, animal breeder, agronomist, importer of new plants, trees and animals, and an experimenter of the highest order in his day, a real pioneer in agri-

cultural research. He used his vast estates and wealth to operate the first extensive agricultural experiment station in America. He kept ever in touch with his contemporary pioneer, Arthur Young, of England and France, who did the same for experimental agriculture and horticulture in the Old World. When George Washington was not running the U. S. army or the U. S. presidency or building up the U. S. constitution, he was running the U. S. agricultural experiment station as his own private vocation.

What better than to spend a part of one's leisure with the fruit trees? Progress is likely to increase leisure. Increased leisure will be more rope for fools to hang themselves with, or a stronger, higher ladder for the wise to climb with.

The home with its garden and orchard may well be an Eden the year around. It need not be excessively hot or cold; it need not be spoiled by much noise, gas

or dust of traffic; it may produce much of life's necessities; it may ever be molded by its owner into more perfect beauty and content; it may ever be improved and, in so doing, improve its habitants. Its trees reach up toward the heavens whither its owner's spirit often soars. Its flowers and fruits feed both body and mind. The living things are companions to the living people. Birds and insects coming to the trees add their sprightliness to the whole association. Heaven's sunshine brings the orchard power from far beyond this earth's domain, feeding the owners with more than a trace of the sublime. Starlight falls on the leaves and boughs by night, with its delicate and perfect touch adding charm and grace ineffable. The trees with the song and the chirp and the gleam of the life and the light around them constitute the perfect surrounding for the happy man who is neighbor to all men, under his vine and his fig tree.

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THE NEW KIND OF MATTER: ELEMENT ZERO OR NEUTON

By Dr. W. D. HARKINS

PROFESSOR OF CHEMISTRY, UNIVERSITY OF CHICAGO

THE year 1932, which has just closed, will always be memorable in the history of human progress as that in which Neutron, the most remarkable of all the known kinds of matter, was discovered. Like all the earlier fundamental types of matter called elements, neutron is made up of atoms, but these possess a remarkable, previously unknown characteristic—that is, while they are like all other atoms in being electrically neutral, they are excessively small. Thus they are so minute that more than a million-million of these new atoms, or neutrons, could be contained in the volume of any ordinary atom and still leave some space which is not occupied. Since a neutron has about the mass of an ordinary atom this means that its density is excessively high. Thus if a lady's thimble could be filled with the neutrons in contact, the material in it would have a weight greater than that of all the warships of all the navies of the earth.

However, this new material could neither be held in a thimble nor in a heavy tightly sealed metal box, since it passes easily through any known material. That is, these neutrons are so minute that they pass very readily through other atoms without producing any disturbance or indeed any noticeable effects.

Other particles of somewhat the same size and weight as neutrons have been known for two decades, but they have always been charged with positive electricity. Any such positive particle

serves as a nucleus, around which there gathers very quickly a diffuse cloud or aura of negative electricity. The nucleus, together with the surrounding negative cloud, constitute what is commonly known as an atom, the whole of which has a volume a million-million times as great as that of the nucleus alone. It is usually considered that this diffuse cloud which collects around the positive nucleus of an atom is made up of negative electrons. The number of these is determined by the charge on the nucleus. Thus the lightest ordinary atom is that of hydrogen, the electronic cloud of which consists of only one negative electron, which is held by one equal positive charge on the proton which serves as the nucleus of this atom. The number which gives the value of the total positive charge on any nucleus, and also the number of electrons in the surrounding cloud, is called the atomic number, and this is 2 for helium, 7 for nitrogen, 8 for oxygen, 26 for iron and 79 for gold.

All these elements have chemical and physical properties which are more or less repeated by other elements. Thus sulphur (16) is somewhat like oxygen (8), and silicon (12) is somewhat like carbon (12).

Not so, however, with element zero, which is totally different from all the other elements, just as the number zero is different from any positive whole number. Since the nuclei of the atoms of this element carry a zero electrical

charge they are neutral, which suggested that the atoms be called neutrons.

The neutron, unlike other nuclei, attracts to it no cloud of negative electrons. This remarkable characteristic is an obvious result of its electrical neutrality. The minute size of this atom is, then, due to the fact that it always exists as a nucleus alone without any surrounding electronic cloud.

Neutrons were discovered early in 1932 in the rays sent off by the light element beryllium (atomic number 4) when a small piece of this material was bombarded by helium atoms flying at about nine thousand miles per second. The experiments were carried out by Irene Curie Joliot, the daughter of Madame Curie, and her husband, M. Joliot, but the fact that the rays contain neutrons was first recognized by Chadwick of Cambridge, England.

That the nucleus of an atom of beryllium contains a neutron was indicated in 1915 by a curious arithmetical discrepancy. According to the hydrogen-helium theory of atom building, developed at that time by the speaker, the atomic weight of any light element of even number should be twice its atomic number, and this is in general true. The single exception was beryllium, which, since its atomic number is 4, should have the atomic weight 8, while the actual weight is 9. To explain the discrepancy it was assumed that the beryllium nucleus contains not only two helium nuclei, each of mass 4, but also a neutron, or electrically neutral particle of (very nearly) the mass of a hydrogen atom, which seemed probably to consist of a closely united proton and electron, while a hydrogen atom consists of these same two particles relatively very far apart.

Not only was the existence of the neutron predicted but also its mass and properties were given in 1920 by Harbins (April 12) and by Rutherford (June 3), both of whom assumed the

neutron to be one of the fundamental particles concerned in the building of other atoms.

It is apparent, from the description already given, that the neutron is the only atom which possesses the unique characteristic of being at the same time an atomic nucleus and a complete atom. Since it is a nucleus it is best studied by the methods used to investigate other nuclei, and these are extremely simple.

When a beryllium atom is struck by a helium atom moving at a rate of about nine thousand miles a second, a neutron may be emitted at about 20,000 miles per second. This neutron may pass for thousands of feet through air without producing any apparent effect, but if by chance it strikes the nucleus or center of an atom in the air very remarkable effects may be obtained, and these may be revealed by photography.

Atoms which move through air at the rate of ten thousand miles a second may be made to produce tracks, which appear as brilliant white lines, by means of an apparatus devised by C. T. R. Wilson. An electron produces a dotted, crooked line; a hydrogen atom, a fine straight line; and any other atom a heavy straight or slightly curved line. Neutrons are the only atoms which produce no tracks at all.

If a fast helium atom hits the nucleus or center of a nitrogen atom, the single track of the helium atom changes into two tracks, one very fine, which shows that hydrogen has been produced, and one shorter and much more coarse, which shows, from the lengths of the tracks, the angles and the atoms involved, that an atom of oxygen has been formed. Thus helium and nitrogen are converted into hydrogen and oxygen, which involves both a disintegration and a synthesis of an atom, and one of the dreams of the alchemists is realized. In this process energy is converted into mass.

The neutron produces no track in the

apparatus, but when moving at the rate of about twenty thousand miles a second it may collide with the nucleus or center of a nitrogen atom. In this case Dr. Feather has shown that the neutron adds itself to the nucleus, which splits in two; into an atom of helium and one of boron, while Harkins, Gans and Newson have also secured photographs of such disintegrations and find that the nuclei seem to exhibit different definite energy levels or quantum states.

Whenever a neutron adds itself to another atom mass is lost and converted into energy, and this gives a high velocity to the fragments of any atom which may be disintegrated.

A simpler case to discuss is the addition of hydrogen to a heavier atom. It will be seen that heavy atoms, like my listeners, do not like decimal fractions. The weight of a hydrogen atom is 1.0078, while the weight of a heavier atom is in general a whole number. Thus, if a hydrogen atom is added to a heavier atom, such a fluorine of weight 19, a neon atom of weight 20 is produced, and the mass 0.0078 is converted into energy. Thus the decimal part of the mass of a hydrogen atom loses the form of ordinary mass. This small amount of mass represents a large amount of energy equivalent to the action of seven million volts on an electron. This energy causes the neon atom to be unstable, since it can not hold this excess of energy, so it splits apart into two parts, presumably into an atom of helium and one of oxygen. Such experiments were carried out in 1932 by Cockcroft and Walton.

The amount of energy which should be liberated in such a transformation of hydrogen was calculated in 1915 by Harkins and Wilson by the use of Einstein's relativity equation, which indicates that one gram of mass is equal to a number of energy units (ergs) equal to the square of the velocity of light in centimeters per second. Harkins and

Wilson showed that the amount of energy given by the conversion of one pound of hydrogen into a heavier atom gives in general as much energy as the burning of ten thousand tons of coal.

Since hydrogen can be bought at a cent a pound, coal at five dollars a ton costs five million times more for the energy produced than hydrogen. The difficulty in the use of this atomic transformation of hydrogen as a source of power lies in the small size of atomic nuclei. Thus both the nucleus of the hydrogen atom, which acts as a bullet, and the heavier nucleus, which must be hit, are so small that a great many hydrogen nuclei must be fired from an electrical gun at high speed, in order to obtain a single nuclear collision, or hit. All the hydrogen nuclei which do not hit are wasted.

The experiments of Cockcroft and Walton show that the magnitude of the energy actually produced is just that calculated by Harkins and Wilson, equivalent to 7 million electron volts. This thus serves as a confirmation of Einstein's equation developed from his special theory of relativity.

Thus it is found that atoms, such as neutrons and hydrogen atoms, which have a decimal fraction in their atomic weights (hydrogen 1.0078, and the neutron 1.0067), lose this decimal part of the weight when they unite with a heavier atom, and the large amount of energy thus liberated disintegrates the atom which is temporarily formed. Usually the atom splits into helium and whatever else is left.

However, the decimal mass of a helium atom is relatively small and amounts to less than 2 million electron volts, so fast helium nuclei often add themselves to other nuclei on collision and thus build up heavier atoms, since the atom which is formed is either able to hold this smaller excess of energy, or else it is liberated as radiation.

Just how important a particle is rep-

resented by the neutron is not entirely known, since it was discovered only a few months ago. However, the most fundamental particles now known are the electron (negative), the proton (positive), and the neutron (neutral). The neutron may be (1) a proton and an electron united with an energy of about a million electron volts, or (2) a more fundamental neutral particle, which, when combined with a positive electron, becomes a proton. At present the known facts seem to be somewhat more in accord with the idea that it consists of a proton and an electron, that is, that its composition is the same as that of a hydrogen atom, though its volume is excessively less.

The possible great significance of the neutron is emphasized by the rapidly growing idea that all atomic nuclei consist merely of neutrons and protons. This possibility was indicated about ten years ago in connection with a formula developed both by Masson and by the

speaker. The idea that this formula represents the constitution of all atomic nuclei has been developed into a theory by Heisenberg, a prominent theoretical physicist.

The most important relations which are apparent are: (1) In general one proton, but not more than one, unites with a single neutron; (2) almost all the neutrons in atomic nuclei exist in the form of pairs; (3) almost all light nuclei are built up from helium nuclei, which may be formed from neutrons and protons.

While before the discovery of the neutron there were facts which seemed to a few to indicate that such a particle should exist, the discovery of its existence and of the fact that it adds itself to other nuclei will have, in the next few years, a remarkable influence not only upon the science of the constitution of matter but also upon that related philosophy which has become so influential during the last half decade.

PLANTS THAT FORM REEFS AND ISLANDS

By Dr. MARSHALL A. HOWE

ASSISTANT DIRECTOR, THE NEW YORK BOTANICAL GARDEN

SINCE the days of Charles Darwin, the corals have enjoyed a world-wide fame as reef-builders or island-formers. Poets have acclaimed the wonderful achievements of the "lowly coral insect." Scientists, while unwilling to admit that corals are "insects," are unanimous in accepting them as members of the animal kingdom and in crediting them with very important activities in the way of building up islands or atolls, where once only salt water was visible.

To-day, however, we are concerned with plants that are active and important in the same way. Some of these plants have a superficial resemblance to the corals, and the earlier naturalists

did not always distinguish the two groups clearly. These plants, which are members of the large group known to botanists as the algae, secrete or precipitate lime from the surrounding water and sometimes become as hard and as stone-like as the corals themselves. The fact that plants, at least at times and in places, are fully as important as the corals in reef-building and land-forming has received no particular emphasis until rather recent years. The beginning of this belief may be traced to the publication, in 1904, of the report of the Coral Reef Committee of the Royal Society of London. This report dealt particularly with the island of Funafuti, of the Ellice Islands group in the

"South Seas." Funafuti was selected for intensive study by this committee because it was believed to be a "typical coral island" or atoll. Borings were made at various points, one of these to a depth of more than 1,100 feet. The cores brought up by the drill were analyzed and the different organisms contributing to the upbuilding of the island were listed in order of their relative importance. The first rank was given to *Lithothamnium*, meaning certain lime-secreting plants belonging to the group known as the red algae. The second rank was assigned to *Halimeda*, meaning certain lime-secreting plants of the green algae class. Third rank was given to the Foraminifera, a group of microscopic organisms belonging to the animal kingdom. The fourth rank went to the corals. So Funafuti is apparently "a true coral island," in the upbuilding of which the corals have played a minor part. The fact that the investigators, in this case, were for the most part zoologists, should relieve botanists of any possible suspicion of trying to filch the coral reefs and islands away from the zoologists! There should doubtless be a new name for "coral reefs" that are not coral reefs, but words and ideas that are once imbedded in the mental processes of *Homo sapiens* are difficult to dislodge. "Algal reef" and "algal island" lack the poetry, tradition and euphony of the well-established names, even though the latter may be misnomers. That Funafuti is not an isolated instance of the dominance of the plants in this field is indicated by the observations of Finckh at Onoatoa, of Mayor at Rose Atoll, of Setchell at Tahiti and Tutuila, of Pollock at Oahu and J. Stanley Gardiner at the Chagos.

Finckh has stated that a certain "nullipore" (an old name for one of the coralline algae) "is actually the reef-former at Onoatoa" in the Gilbert Islands. Mayor, writing of Rose Atoll,

in American Samoa, says: "The whole visible rock of the atoll consists so largely of *Lithothamnium* that we may call it a '*Lithothamnium* atoll' rather than a 'coral atoll.' "

Setchell, after a visit to Tahiti, in the South Pacific, states that "The conspicuous reef-former, both on the barrier reefs and on the exposed fringing reefs, is *Porolithon onkodes*." This organism with a rather long Greek name is a hard rock-like plant.

J. Stanley Gardiner, distinguished British zoologist, after an expedition to the Chagos Islands in the Indian Ocean wrote: "The reefs of the Chagos are in no way peculiar save in their extraordinary paucity of animal life. . . . However, this barrenness is amply compensated for by the enormous quantity of nullipores (*Lithothamnia*, etc.) encrusting, massive, mammillated, columnar, and branching. The outgrowing seaward edges of the reefs are practically formed by their growths, and it is not too much to say that, were it not for the abundance and large masses of these organisms, there would be no atolls with surface reefs in the Chagos."

Pollock, in a rather recent paper on the fringing and fossil reefs of Oahu, the best-known of the Hawaiian Islands, states that "the organisms chiefly contributing calcium carbonate to both fossil and fringing reefs are corals and coralline algae. The algae contribute more than the corals."

Bermuda was commonly considered a coral island, until the studies of Alexander Agassiz and Henry B. Bigelow indicated that corals have played a rather minor part in its formation.

Your speaker was once becalmed, or nearly so, for two days out of sight of land in a small sailboat on the Bahama Banks, where, for many miles, the water is only from ten to one hundred feet deep. Except when agitated, the water on these banks is of crystalline clearness, and when a calm leaves the surface

as smooth as a mirror, it is very easy for an observer in a boat to get a rather accurate idea of the nature of the plants and animals growing on the compacted sand and rubble at the bottom. One may then note that the corals are rare on the Bahama Banks and that the lime-secreting algae are very abundant.

There are, however, doubtless such things in the world as coral reefs, the upbuilding of which has been due chiefly to corals; a notable example of such seems to be the famous Great Barrier Reef on the northeast coast of Australia. But there is increasing evidence that the atolls, reefs and low islands of the Central Pacific, long considered the classic examples of the results of the activity of corals, are in a dominant way monuments to the long-continued growth of lime-secreting plants belonging to the marine algae.

Corals thrive in rather shallow water. Dr. T. Wayland Vaughan has stated that 25 fathoms is the greatest depth at which reef-building corals work effectively. The coral-like plants flourish from low-water mark down to depths of at least 100 fathoms—a depth four times as great as that enjoyed by the corals. The corals are confined to the warmer parts of the ocean. The stony coral-like algae are found not only in the tropics but occur also in great banks off the coasts of Norway, Iceland, Greenland, Spitzbergen and Nova Zembla. In the tropical Dutch East Indies, Dr. Weber-van Bosse has described and photographed reefs of coralline algae exposed at an extremely low tide and stretching away "as far as the eye can reach."

Neither the corals nor the lime-secreting sea-plants can survive for any great length of time above the low-water mark. When the corals and coral-like plants, working together or more or less separately for centuries, have built up a mass of limestone rock close to the surface of the sea, the red mangrove tree,

with wonderful adaptations for a semi-aquatic life on a young reef, such as boring, stilt-like roots, very often appears and carries on the work of forming dry land where once there was salt water. The arching, branched, widely spreading roots of this remarkable tree form an admirable trap for catching driftwood and a great variety of organic and inorganic débris. Soon there is a sort of muddy soil that will sustain other aquatic or semi-aquatic plants of the flowering or seed-bearing group and in the course of time there is formed a soil that is adapted to plants of drier land. Some of the older navigators of smaller craft along the shores of southern Florida say that low uncharted islands have appeared within their memories. Sometimes there is a gradual rise of the sea-bottom or a more abrupt upheaval that helps to transform a wave-swept reef into an island. In remote geological ages, as is well known, there have been mighty upheavals that have lifted mountain ranges of the present out of the seas of the past.

Your speaker has recently enjoyed the privilege of examining specimens of limestone from an ancient reef in the Coast Range Mountains of Santa Barbara County, California. This old limestone of Eocene age, recently investigated by geologists of Stanford University, is said to be about 225 feet thick. Although now more than 3,000 feet above the present level of the sea, this reef consists very largely of the remains of lime-secreting marine algae, with microscopic cell-structure beautifully preserved, though parts of the deposit are made up chiefly of minute lime-secreting animals of the Foraminifera group. No corals are found. There is a somewhat similar marine-algal reef now high and dry in the Santa Monica Mountains in Los Angeles County. There are others in southern Europe, northern Europe, and northern Africa.

It is of interest and importance to note that most of the coral-like sea-plants contain large quantities of magnesium carbonate as well as of calcium carbonate, while the corals are notably deficient in magnesium. It seems highly probable that the magnesian limestones, known technically as the dolomites, owe their origin to the chemical activity of plants, that is to say, of algae. The researches of Willstätter, eminent organic chemist of Germany, indicate that magnesium is an essential element in chlorophyll, the green pigment characteristic of all plants except the fungi and bacteria. The association of magnesian limestones with the chlorophyll-bearing lime-secreting plants seems perfectly natural and logical.

In addition to the rather large, easily seen lime-secreting plants of the sea, there are also in our fresh-water streams and lakes and in hot springs microscopic

algae, mostly belonging to what is known as the blue-green group, that precipitate lime when growing in water that is more or less charged with a form of lime in solution. There is a considerable amount of evidence, not, perhaps, altogether incontestable, that these minute algae were the producers of the extensive deposits of lime that are found among the sedimentary rocks of the earliest geological ages. The researches of the late Dr. Charles D. Walcott in the Rocky Mountains, of Dr. David White in the Grand Canyon, and of Professor E. S. Moore in Canada are of special significance in this connection. But that is another story. For to-day we rest with a reaffirmation of our belief that in the formation of many, if not most, of the so-called coral reefs or islands, lime-secreting plants—the algae—have contributed more than have the corals.

BORDERLINES OF SANITY

By Dr. NOLAN D. C. LEWIS

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IN these times of shifting values, heavy financial losses, forced struggles for vital existence and increasing competitive activity, including disconcerting noises from all kinds of machinery, the result of the so-called "machine age," the nervous and mental organization of the human being is called upon to carry an unusually heavy environmental load, a burden which at any time may strain the individual to and beyond his capacity to stand the situation in which he finds himself. The actual danger to mental health inherent in such situations, while an important factor, is perhaps no greater than the devastating fears and apprehensions engendered and enhanced in those, who under the additional stress are developing pernicious habits of self-scrutiny, which tend to

overrate the significance of simple mental fatigue or to misinterpret curious or slightly abnormal mental traits as signs of an unsound heredity or of a pending disturbance of mental integrity.

Man, in common with all other living things, is an adaptable being trying to preserve his organic unity and equilibrium; and in spite of the fact that he is controlled to a large extent by primal instinctive impulses, as hunger, sleep, fear, aggressive trends and love strivings, which have to be adjusted to the laws of his complex society, he has succeeded by and large in this type of adaptation. Man is entirely a part of nature, and nature does nothing by accident or by chance, but only by means of universal principles. From the beginning of life until death the one ever-

present factor in a living being is its endless adaptation, which includes all the best expressions of the creative side of life; all in art, music, the drama, literature, the great mechanical inventions, the profound scientific hypotheses and the various systems of philosophy and religion.

Man is the outcome of a gradual evolutionary process, during the course of which the physical organs and the mental capacities and tendencies have developed together. Therefore, any division of traits into "physical" and "mental" is only a convenient artificial designation for the purposes of studying certain aspects. The person is a unit in spite of the complexity; each self is a unit in the group to which it belongs, and the welfare of each individual is most intimately bound up with this group. Therefore, human society is one of the most, if not the most, important features of our natural environment, and the mental state and capacities play the major rôle in the adjustment to these groups and societal situations.

The basic qualities of mind are apparently universally the same or very similar. The mind of primitive man, or the so-called savage, works after the same fashion, just as keenly and accurately as that of an educated man, the principal difference being in the store of facts. The primitive mind is more apt to reason from false premises, as the knowledge acquired is different from that characterizing the civilized educated mind, but aside from the content, the psychological mechanisms are practically identical in their behavior, a similarity which naturally holds good, with a few exceptions, into the realms of mental disorder.

Until comparatively recent times in terms of history, the idea that mental disorder was a state entirely different from mental health was universal among physicians, as well as among people in general. But it has been

gradually discovered that the so-called abnormal mental manifestations are quite analogous to the normal mental processes, the difference being principally a matter of degree. This is true also of the other aspects of the body; whether one be healthy or sick, the breathing, circulation, digestion and all other vital activities are controlled by the same chemical, physical and psychological laws of nature. In illness the conditions under which these laws function have become changed, thus making it possible for the same causes to produce different results. There is no very sharp dividing line between health and disease, excepting in those instances where from acute poisoning or infections conditions have changed abruptly. Where the changes in conditions are sudden, the contrast is recognized by every one.

In mental conditions the change from health to disorder may be so gradual that at times even the experienced physician is unable to tell with certainty the extent of the trouble. Often there are intermediary stages in the transition, for which there is no gage to distinguish the healthy from the sick. There are no two individuals who are completely in accord as far as their constitutions, intellect and emotional equipment are concerned, so what is called "normal" can be little more than a notion which changes from time to time to suit the concept of averages. As far as the mind is concerned, there are many intermediary grades or borderline states which must never be judged from single individual symptoms. From simple or curious eccentricities of character to states of paranoia or from excited exhilaration to pathological maniacal excitement, the intermediary steps are very numerous, and it is not a question of individual peculiarities, but a change in the entire personality. A mental trait which in one person may be entirely normal, in another may be a sign of serious disor-

der, so great is the difference in the ways people express their painful or joyous feelings or conduct themselves in their adjustments to the various situations in life. Neither a great exaggeration nor a marked suppression of feelings, opinions and beliefs is in itself abnormal, because such a degree of activity may be normal and characteristic for one person in certain settings and definitely pathological in a person with a different set of characteristics. The matter of abnormality can be decided only by a study of the particular case, taking the total life situation into consideration along with the habit patterns in an attempt to determine just how far the total psychic accomplishment has deviated from its original or from its average efficiency.

For many years the so-called "degenerative signs" were held to indicate the existence of mental abnormalities. These signs or stigmata include peculiarities in the shape of the skull, palate, ears, hair distribution, and some kinds of "birth marks." But numerous scientific studies have shown that, aside from an abnormally small skull, which means an abnormally small brain as found in some types of feeble-mindedness, these signs of degeneration are not reliable, having little, if any, bearing on the question; since they may be present in persons of perfect mental health or may be absent in those with advanced constitutional mental disorders.

In our social organization a person is supposed to allow himself to be guided in his contacts with his fellow beings by the accepted reasonable motives, and at the same time be capable of safeguarding his own interests. We assume that every person who has developed and been trained in the accepted ethical views and notions of our social state shall have acquired the necessary moral concepts by which to direct his own conduct. Any radical departure, in speech or action, from these laws of society,

particularly if it interferes at all seriously with the supposed welfare of others, places a person at once under the suspicion of having mental disorder, antisocial or criminalistic tendencies, and should he persist in this behavior, he is eventually segregated in a hospital for mental disorders or a prison. In evaluating these situations one must recognize that just as upon the one hand not every act of a mentally abnormal individual is abnormal, so upon the other hand the capability of acting according to the recognized and accepted right and wrong principle is not always present in the normal. Morbid emotions, ideas and impulses may at any time conflict not only with the power of acting correctly, but even with the recognition and appreciation of the social and personal obligations in the situation. Such emotions and impulses originate in the unconscious part of the mind, and while it is a contradiction in terms to speak of an "unconscious" idea or feeling, it is not illogical to talk about unconscious tendencies and drives to action, which create behavior problems outside of the usual control of the individual's conscious desires. In any given situation the possible influence of these factors should be known by people in general, and they must be acted upon intelligently by physicians and jurors in particular, to determine whether a person is entirely deprived of the use of his intellect or whether he is merely incapable of adjusting his actions to the demands of circumstances.

Along the borderlines of sanity, we find states in which mental disease is only partly developed, and those in which the peculiarities and inadequacies are only paroxysmally present; and also many states of disorder which are revealed only through the writings and art productions of the individual. We frequently hear geniuses referred to as borderline types, a statement which is true only in definite individual in-

stances. There is no reason why a genius should not develop a mental disorder, or a person having a mental disease show the traits of a genius, but geniuses as such are not pathologic; they are prodigies, people endowed with superior faculties, great energy, tremendous capacity for work, a combination that can be defined only in terms of its own unique mental and temperamental processes, traits, qualities and products.

It should be recognized from the very beginning that many children are constituted differently from their companions of the same age, and may not be able to adapt themselves to the general mould, but we should not consider every child in danger of a mental disorder whose psychic demeanor differs from that of his companions, as not infrequently to the astonishment of those who have anticipated trouble, these peculiar children later become the renowned members of human society. Children with extraordinary capabilities may be just the ones who rebel against restraints and systems of education and training, modeled according to some established plan, while model children are sometimes the ones with an intelligence adapted to and not exceeding the demands, or with dwarfed talent, or suffering from a lack of opportunity for development of their capacities. Some persons seem to be congenitally possessed of an individually defined life

thirst of such intensity that it can not be quenched by any ordinary way of living: a situation which drives the individual into various types of pathological behavior. Interrupted ambitions, lost hopes and thwarted love lives give rise to pathological expressions of the personality, with flights into alcoholism and drug habits which are more than apt to become borderline mental disorders.

Every event in life has both an external and an internal cause. Every question of this nature has two sides. We can always consider it from these two points of view, but until we can control all the conditions of life from love, conception, birth and infancy to old age and death, and also the conditions that underlie the civilized societies, there will remain a wide field of problems that we can solve only by watching, recording and comparing the great age-long and world-wide experiments nature has always made and will continue to make. If the public is to be instructed at all in matters of mental health, and it certainly should be, the information must be more complete than it has been in the past, and must be freed from the destructive influences of fear, which is always bred in misunderstanding. For the present there is a good slogan to keep in mind concerning mental states: "It is not so much what a person says and does, but it is the manner in which he says and does it."

SCIENCE IN CHICAGO

By AUSTIN H. CLARK and LEILA G. FORBES
U. S. NATIONAL MUSEUM

"THE time is not far distant when culture, civilization's chief adornment, will give an added lustre to Chicago's fair fame; and the height of her buildings, the size of her grain elevators, and the reports of her slaughter houses will be of secondary importance as compared with the scientists, artists, scholars and musicians she has fostered." So wrote Joseph and Caroline Kirkland in 1894. As far as science is concerned, that time has now arrived; Chicago has become a most important center for all types of scientific work, and for many types the most important center in America.

As the main front door to the vast, rich, unsettled regions to the west, the land of opportunity and hope, Chicago in the early days was naturally almost entirely concerned with things material and practical. It was a typical frontier city, living close to the fundamental necessities of life with little thought of anything beyond making the most of its commercial opportunities. Extremely active in all lines of work bearing directly and immediately upon their daily lives, the people of Chicago were in those early days in a state of cultural abeyance.

Cultural abeyance rarely is of long duration. The human mind seems to require something beyond a mere routine existence; it is not satisfied with the simple planning day by day of ways and means for securing the fundamental necessities of life, or even the material luxuries. Just as soon as an adequate provision of the necessities of life becomes assured for any considerable portion of the population, the craving for the development of the non-material side

of life and the desire to explore the mysterious fields lying beyond the realms of common knowledge begin to assert themselves.

The desire for cultural advancement and for scientific research is always particularly strong in a community where over a period of years the people's attention has been more or less severely concentrated on things material. And besides this, an interruption of the cultural continuity in the history of a community enables that community upon the reestablishment of cultural life—or rather upon the resuscitation of that cultural factor which, no matter how severely it may be suppressed, can never be eradicated—to build up a cultural and a scientific structure which shall be a new and virile growth free from the limitations and traditional inhibitions that in the older communities so often operate to retard true cultural progress, or to limit a cultural advance to a relatively small portion of the population.

As was quite natural, it was the purely practical side of science, finding more or less immediate social application, that first received attention in Chicago. So up to 1850 we find only organizations having to do with medicine and with applied mechanics in its broadest sense. Science at that time was largely a structure composed of a few imperfectly appreciated facts that formed a nucleus for an elaborate nebula of guesswork, strongly colored and infiltrated with prejudice and preconceived ideas. Yet scientific curiosity was not lacking, as is evident from the existence of various small commercial museums containing collections of ob-

jects calculated to interest the public, and fitted for the presentation of more or less elaborate theatrical performances.

In 1851 Northwestern University was founded, followed in 1855 by the University of Chicago, in 1856 by the Chicago Historical Society and in 1857 by the Chicago Academy of Sciences. Science in the fifties, therefore, assumed a more truly cultural aspect, and at the same time became organized.

In the sixties, as a result of the increase and improvement in transportation facilities, Chicago came to be recognized as the best location for the headquarters of organizations of nation-wide scope, and beginning in 1863 many of these became established there. It was in 1868 that the first Chicago meeting of the American Association for the Advancement of Science was held.

The World's Columbian Exposition or "World's Fair" of 1892-93 brought to Chicago many assemblages of objects of scientific interest from all over the world, and also attracted attention to the development of applied science in this country. Naturally, therefore, it gave a great impetus to the further establishment and expansion of local scientific institutions.

Chicago was incorporated as a city in 1837 when its population was only 4,170; in that same year there were organized a medical college and an institute largely devoted to science.

The early history of medical organizations in Chicago was that of a sequence of several evanescent societies mostly coming to an abrupt end through professional and personal dissensions among the members. The Cook County Medical Society held its first meeting on October 3, 1836, and the Chicago Medical Society was inaugurated during the first quarter of 1850. These two societies were merged at a meeting held on April 5, 1852.

The Rush Medical College was incorporated on March 2, 1837. In the *Chicago American* for March 25, 1837, we read: "This act may be regarded as not the least of the favors which Chicago has received at the hands of the state. Being the first institution of its kind in Illinois, or indeed west of Cincinnati and Lexington, it must soon possess advantages of location which but few medical schools enjoy. With such a situation, if it receives the fostering care of the public, it can not fail to become an ornament and an honor to our infant city. The benefits resulting from the establishment of literary and scientific institutions in a community are very great." The college building was erected in 1844, and the first lecture in the new building was given on December 11, 1844. The Rush Medical College was affiliated with the University of Chicago in 1898, and became a part of the university in 1924.

On the night of January 3, 1837, a number of Chicago mechanics met at the Eagle Coffee House for the purpose of organizing a Mechanics' Institute. At a subsequent meeting held on January 21 a constitution was adopted, officers elected and arrangements made for starting a library and museum. Five years later a reorganization was effected, and early in 1843 it was chartered as a corporation.

The objects of the society as set forth in its constitution were "to diffuse knowledge and information throughout the mechanical classes; to found lectures on natural, mechanical and chemical philosophy and other scientific subjects; to create a library and museum for the benefit of mechanics and others; and to establish schools for the benefit of their youth, and to establish annual fairs." The only requirement for membership was good moral character.

With the incorporation of the institute the *Prairie Farmer*, then the best

agricultural monthly in the West, was made its official organ, and the mechanical department of that magazine was edited by John Gage, a prominent and active member. In the year 1844 William H. Kennicott was elected first vice-president.

In 1845 the first annual fair under the auspices of the Mechanics' Institute was held, and proved a marked success.

The program of the institute consisted of lectures on the arts and sciences delivered by the best available men in the city. They were prepared for the special benefit of the members of the institute rather than for the general public. As examples of the high quality of these lectures, it may be mentioned that in 1850 Hon. William Bross gave a course of interesting and instructive addresses on geology, and Dr. James V. Z. Blaney lectured on various occasions on chemistry as applied to the arts.

In 1850 William H. Kennicott was elected president. In this year, too, the Smithsonian Institution donated copies of its publications to the institute.

In 1845 a museum was established in the Commercial Buildings, 73 Lake Street, a few doors east of the Tremont House. An advertisement of the institution published in the local papers assured the public that in it there were to be found the "best collection of specimens in natural history in the West, including an extensive variety in geology, mineralogy, chronology and ornithology. In addition there are several groups of wax figures and a superior collection of cosmographic views." But the special attractions, as was frequently the case in museums of that time, and even much later, consisted of concerts, lectures and explanatory descriptions of the exhibits. Nothing was brought within the walls of the museum that was not "in strict accordance with propriety, morality and religion." Admission was twenty-five

cents for adults and one shilling [twelve and one half cents] for children.

On November 15, 1845, the manager of the museum petitioned the council to remove the license tax, asserting that the museum was strictly "a place of instruction" and therefore should not be compelled to pay a fee. This petition was promptly denied. On February 13, 1846, the museum again appealed for more liberal treatment. On February 26 the board voted to remove the license tax with the understanding that the managers should admit no transient entertainments to their hall. Theatrical performances were also prohibited without additional contributions to the general funds.

Not long after this another application for more liberal treatment was made in which the managers said that they "would be under the necessity of closing the museum unless theatrical performances could be given free of license." This application was referred to a special committee of the council, who reported:

We feel that the efforts of Messrs. Fuller and Sercomb to establish a museum have not been properly appreciated by the citizens, and that they have not afforded that encouragement and patronage which the merits of the museum demand. Your committee find that the museum already embraces a very interesting collection of animals, insects, birds and minerals, together with a variety of artificial curiosities well worthy the attention of the citizens and constituting a nucleus upon which, if adequately encouraged, a museum will grow up creditable to the city and profitable to the proprietors.

An order was passed granting the museum a license for six months at the nominal fee of five dollars.

Digressing for a moment we may note that the newspapers of this period reflect the almost purely commercial attitude of the population. Yet in them we occasionally find articles bearing more or less on science, or at least written on a scientific subject, often copied from

other Eastern or Southern papers, or taken from some other source that was readily available.

Thus in the *Chicago Commercial Advertiser* for Wednesday, April 25, 1849, there is an article on the animalcular theory of cholera, at that time a very serious menace, copied from the *New Orleans Crescent*, and in the same issue there is a poem in the form of a dialogue between Brandy and Cholera in which they address each other as "dread plague" and "foul poisonous drug."

In an advertisement in the *Chicago Commercial Advertiser* for Wednesday, June 13, 1849, we find a notice that "the Chicago Museum, and Gallery of Fine Arts, will open for the season on Wednesday, June 13th, under the management of Mr. Thos. Buckley." In the issue for June 20 the advertisement of the Museum says:

The Manager begs leave to announce that he is preparing a Drummond Light which will be nightly exhibited from an observatory that is now being erected on the top of the Museum Building. The process of generating the gas will take place every afternoon at 3 o'clock to which visitors to the Museum will be admitted free of charge.

The admission to the museum was twenty-five cents, children under twelve, half price.

The Northwestern University was chartered under the auspices of the Methodist Episcopal Church in 1851, and was first opened in 1855 in Chicago. The College and the School of Music were later removed to Evanston, Illinois, but the professional departments have remained in Chicago. This university has fifty-eight professors in the scientific department, including eleven in the dental school.

In 1855 there was established on land given by Hon. Stephen A. Douglas a small Baptist college which was officially known as the University of Chicago, but was also called Douglas University.

This college had on its faculty 10 professors, including the president, and two others. Mr. J. H. McChesney was professor of chemistry, geology, mineralogy and agriculture. The college was divided into four departments—I. Academy, a preparatory school; II. College, with a classical and a scientific course; III. Agricultural; and IV. Law.

Regarding the scientific course we read in the second report of the institution:

With all the admitted excellence of the established curriculum of studies in American Colleges, it were too much to expect that it would be adapted to all the differences of intellectual constitution, and of practical aims. While, therefore, fully realizing the paramount claims of the classical course, the Trustees at the same time have deemed it expedient to provide another, which, with some important variations from the classical, is still believed adequate to the purposes of thorough mental discipline, as well as to many of the practical callings of life.

For entry into the scientific course it was provided that students would be examined in the same studies as for the classical, with the omission of Greek altogether, and of Latin, excepting Latin grammar and reader. For the freshman class in the scientific course the prescribed courses were in algebra and geometry, Latin, Greek, English and history. In the sophomore class the students studied higher mathematics, German, rhetoric and history. The agricultural course required only two years, and the conditions of admission were "the fundamental branches of a good English education." This university was closed in 1886 because of financial difficulties.

The Chicago Academy of Sciences was founded in 1857. Subscriptions were collected amounting to about \$1,500, and a room was engaged in the Old Saloon Building. But the financial crisis of that year put an end to the subscriptions, and as a result the academy languished. As the hard times wore away the enthusiasm of its promoters

revived, and in 1859 a new effort was made, the members of the academy incorporating themselves under the name of "The Chicago Academy of Sciences."

One of the more earnest and enthusiastic workers for the academy was Robert Kennicott, who had long had the idea of building up a museum of natural history in Chicago. By the time he was twenty-four years old he had traveled widely over the entire northwest, and had done considerable work in systematic biology. In 1859 under the direction of the Smithsonian Institution he led an exploring expedition into British and Russian North America which was in the field three years. In 1862 he returned with an extraordinary amount of material in all departments of natural history. His specimens were the property of the Smithsonian Institution, but there had been an understanding that a full series of duplicates should be given to any society or institution he might name that would provide suitably and care for them. He designated as the recipient of these duplicates the Chicago Academy of Sciences, and under the stimulus given by this valuable donation the academy again reorganized, and a new charter was secured from the state legislature.

Professor Louis Agassiz, of Harvard University, had addressed the members of the academy on February 22, 1864, at the residence of Mr. Edmund Aiken, when he had testified to the great value of Mr. Kennicott's work. As a result, about \$60,000 had been raised, and the academy placed upon an enduring foundation.

Mr. Kennicott was elected the curator of the academy. In March, 1865, the Western Union Telegraph Company planned an expedition for the purpose of establishing a route for a telegraph line to connect North America with Asia across Bering Strait. The com-

pany very generously offered to naturalists the opportunity to conduct scientific investigations in a region at that time scarcely known and almost inaccessible. Mr. Kennicott, with others, joined the expedition, sailing from New York on March 21, 1865. While at San Francisco he was notified that at a meeting on April 7, 1865, he had been elected director of the academy. On May 13, 1866, he died suddenly, while alone, on the banks of the Nulato river in Alaska.

On November 12, 1866, Dr. William Stimpson was elected director of the academy to succeed Mr. Kennicott. For many years Dr. Stimpson had been in charge of the invertebrate department of the Smithsonian Institution. He was the first naturalist to dredge systematically on the American coasts, beginning his operations in 1849. In 1850 he had been a student of Professor Agassiz at Harvard. In 1852 he was appointed naturalist of the United States North Pacific Exploring Expedition. During 1865 he had twice visited Washington for the purpose of selecting specimens at the Smithsonian Institution, and succeeded in obtaining very large collections in nearly all the branches of natural history. He added largely to these from his private collection.

On June 7, 1866, the collections and rooms of the academy were seriously damaged by fire. In his report Dr. Stimpson stated that

Half the animals and birds were lost; the extensive collections of birds' nests and eggs were mainly consumed; nearly all the insects were destroyed; the dried crustaceans and echinoderms were all destroyed. The large herbarium was saved, with the exception of the plants of the northern Pacific expedition. The library was much damaged by water, but most of it was still in a condition to be used.

In 1867 the academy joined with the Smithsonian Institution in sending Mr. Ferdinand Bishoff on an exploring expedition for the purpose of conducting

zoological investigations along the shores of the north Pacific. The academy was to pay half the expenses and to receive half the material.

For some time the academy had been considering the construction of a new building, and the loss of its old building in 1866 stimulated it to action. A lot was purchased on Wabash Avenue north of Van Buren Street, and a fireproof building was erected thereon. The supposed fireproof character of this new building which at that time was unique in the construction of museum buildings, led many institutions, as well as private individuals, to send large and valuable collections and private libraries rich in particular departments of science to the academy. This was especially true of the Smithsonian Institution.

At the beginning of the year 1871 a brilliant future seemed assured. Valuable material constantly flowed under the care of the academy, and the enthusiasm of the members steadily increased under the wise guidance of Dr. Stimpson. Besides this, the academy had a large hold on public esteem. It became popular to be scientific, and to foster those things which would aid and advance the investigation of the truths of nature. But on the night of October 9, 1871, the academy's building was completely destroyed by fire, with all its contents, and a further blow was the death of Dr. Stimpson on May 26, 1872.

After a long period of troubles and discouragements, the Matthew Laflin Memorial building was built, Mr. Laflin contributing \$75,000 and the Lincoln Park commissioners \$25,000. This building was dedicated and opened to the public on October 31, 1894.

In 1892 the academy had inaugurated the natural history survey of Chicago and vicinity. This, together with the work of popularizing science, now forms its chief activity.

The first movement which led to the

organization of the Chicago Astronomical Society was made in December, 1862, within the old University of Chicago (Douglas University). It arose from a visit from The Reverend M. R. Fory, who came to Chicago in an endeavor to sell a telescope manufactured by Mr. Fitz, an optician of New York. The price of the instrument was stated to be \$8,000. In order to awaken a proper interest in the purchase of such an instrument, and in the establishment of an observatory, it was determined that the Reverend Mr. Fory should lecture on astronomy in Bryan Hall. This lecture was delivered on December 8, 1862.

After the lecture a meeting was organized, at which Mr. J. Young Scammon was asked to preside, and a committee of five was then appointed with a view of purchasing the "Fitz glass" and of establishing an observatory. The committee held a meeting on December 13, and still another on December 15, to consider questions connected with the purchase of the "Fitz glass." But the committee had learned from Baron Brünnow, of the Ann Arbor University, something of the great telescope made by Alvan Clarke and Sons of Cambridge, Massachusetts, for the University of Mississippi which, on account of the breaking out of the Civil War, had been left on the hands of the manufacturers.

The committee determined upon the purchase of the Clarke telescope, and thereby Chicago became the possessor of what was then the largest and best refracting telescope in the world, with a diameter three inches greater than that of the great telescope at Cambridge, and greater than that at Pulkowa in Russia, the largest refracting telescope in Europe. This telescope, upon being pointed at Sirius, discovered the hitherto unseen, though suspected, dark companion of Sirius. On March 22, 1863, this telescope was purchased.

The observatory tower was built by Honorable J. Young Scammon on the west side of the University of Chicago building. It was named by the trustees Dearborn Observatory in memory of Mr. Scammon's first wife.

The Chicago Astronomical Society was organized in November, 1863, and incorporated by the legislature on February 19, 1867. On July 14, 1887, the society was served with a court order to vacate by October 1 the site on the University of Chicago grounds as a result of the financial difficulties in which the university had become involved. On August 10, 1887, the society voted to accept the offer of a site at Evanston, Illinois, that had been made by the Northwestern University, and the new Dearborn Observatory was dedicated at Evanston on June 9, 1889.

In the summer of 1863 there was established a museum, subsequently known as Wood's Museum, of which we read in the *Chicago Tribune* of July 6:

We make the announcement with pleasure that, through the liberality of two of our public-spirited citizens, the St. Louis Museum has been purchased, and will soon be removed to, and permanently located in, this city. This Museum is much the largest in the West, and in several of its features the choicest one in the United States.

The catalogue of the museum, dated August 17, 1863, bore on the cover the following:

A complete guide to the Chicago Museum, including a description of the wonderful antediluvian monster, the great *Zeuglodon*, catalogue of birds, quadrupeds, fishes, reptiles and insects; microscopes, stereoscopes, cosmoramas, philosophical instruments, minerals, shells, mummies, models and curiosities. Admittance twenty-five cents. Kingsbury Block: Randolph Street, between Clark and Dearborn Streets.

The museum was first opened to the public on August 17, 1863.

The original collection was assembled by Edward Wyman, and consisted chiefly of such objects as were commonly

exhibited in museums at that time. But among the attractions was the skeleton of a *Zeuglodon* 96 feet long.

On the upper floor was the "hall of paintings," where some really fine works of art were shown. In an exhibition hall at the rear there was nightly unrolled a panorama of the city of London. It cost an additional fifteen cents to see this. So popular was this museum that during the first six weeks of its existence fully ten thousand visitors were entertained there.

The museum consisted of six distinct departments. According to the guide to the collections it contained at the time of its establishment 62 cases including chiefly birds, 13 cases of insects, 1 case of American bird's eggs, 4 cases of seashells, 4 large cases of minerals, 5 cases of miscellaneous curiosities, 27 busts, some Egyptian mummies, 58 miscellaneous specimens not in cases (zoological, anthropological and geological), a model of the Parthenon, and a model of the capitol at Washington.

A change in the management took place on January 25, 1864, at which time Colonel J. H. Wood became the proprietor. Among the new attractions in the department of natural history was a sea-lion from Barnum's collection.

The name of the museum was changed to Aiken's Museum in November, 1869, but in June, 1871, Colonel Wood again resumed the management, and the name Wood's Museum was restored. This museum and its contents were entirely destroyed by the great fire on the night of October 9, 1871.

It is of interest that the *Zeuglodon* skeleton was the first, and only complete, skeleton of this great creature ever found, with the only complete skull. Another specimen of special interest in this museum was the head of a fossil beaver (*Castorides ohioensis*), which was later acquired by the Chicago Academy of Sciences. Shortly before the fire Dr.

Stimpson sent it to Professor Agassiz at Cambridge, Massachusetts, who wished to make a plaster cast of it. It was not returned until after Professor Agassiz's death in 1873 and so escaped destruction.

During the Civil War Dr. C. V. Riley published a number of articles on entomology in the *Prairie Farmer*, with which he later became associated as reporter, artist and editor of the entomological department. This led to his appointment as state entomologist of Missouri in 1868, and through this appointment subsequently to the organization and development, under his guidance, of what has now become the Bureau of Entomology in the Department of Agriculture at Washington.

The seventeenth meeting of the American Association for the Advancement of Science was held in Chicago from August 5 to 12, 1868. In his address to the members of the association Dr. Frederick A. P. Barnard, who had been the president of the association in 1866, said:

The city which, on the present occasion, has extended to American science the encouragement of its generous hospitality, is one which has been heard of before in connection with large assemblies professing to represent our country in one or another of its aspects. But this is the first time that a great convention has been assembled here which could claim to be called in the strictest sense national; a convention having no aims likely to engender suspicion in any quarter, and intent on no proceedings liable to be watched by any jealous eyes. For this is the first of the national conventions which the political, social, commercial and intellectual prominence of Chicago has attracted to this spot, of which the declared platform has been entirely catholic and universally acceptable; the first which could justly hope to enlist the sympathies of all parties, creeds, all states, all sections alike. It is gratifying to know that there is one subject in regard to which the whole world of mankind have a common interest, one subject on which there can be but one party. Such a subject is that which occupies us. For the object of science is truth. Its progress is the progress of civilization, its encouragement is the encouragement of the arts

of life, and the enlargement of the comfort and the happiness of the human race.

Two hundred and fifty-nine names were registered in the book by members who attended the meeting, and 475 new members were chosen. One hundred and fifty-one papers were presented, most of which were read, and some of them discussed at great length.

The sessions of the association were held partly in the Library Hall of the Young Men's Association and other rooms of the same building, and partly in the lecture rooms of the First Baptist Church.

At this meeting Colonel J. W. Foster, of Chicago, was elected president, and the association voted to hold its next meeting at Salem, Massachusetts.

It is recorded that through the extraordinary liberality of the directors of many of the railroads that center in Chicago, the members of the association had an opportunity, after the final adjournment of the meetings, to make excursions to points of scientific interest, and not a few availed themselves of the privilege to visit the Coal Valley near Rock Island, Illinois, the mines of Lake Superior, or the newly planted germs of a city on the Missouri River—Omaha. A small party proceeded from Omaha, on the invitation of Hon. W. B. Ogden and Captain J. B. Turner, over the whole length of the Union Pacific Railroad to a point more than 60 miles beyond Benton, and on the afternoon of August 17, after dining in the construction train of General Casement, rode over a mile of road which had been finished with the rails which their own train had brought forward two hours before.

The Chicago Microscopical Club, out of which grew the present State Microscopical Society of Illinois, was formed on December 12, 1868.

The scheme of holding a permanent exposition in Chicago first began to at-

tract public attention in 1871. The Chicago Inter-State Industrial Exposition Company was organized in March, 1873, and the exposition was opened to the public in September, 1873.

In March, 1885, the Chicago Academy of Sciences proposed to make its valuable collection, illustrating the several departments of natural history, a part of the regular exhibition for two years, and suitable rooms were provided for it.

At the annual meeting of the stockholders on November 14, 1885, it was moved that the executive committee inquire into the propriety of holding an "Indian Exhibition" in the building, either in 1886 or 1887. The motion was carried unanimously, and steps were taken to gather representatives of the various Indian tribes of the West and Northwest, together with their squaws, papooses, dogs, teepees and accoutrements, as well as a collection of old Indian implements and curiosities, to make an exhibition at once complete and full of historic interest.

The College of Physicians and Surgeons of Chicago, founded in 1882, was united with the University of Illinois in 1897, was separated from it in 1913, but is now again united with that university as its College of Medicine.

On May 5, 1846, a National Medical Convention of delegates from medical societies and colleges in the whole nation convened in New York City. A second meeting was held in Philadelphia in the year following, and on May 5, 1847, this body resolved itself into the American Medical Association. The "Transactions" of this association up to and including volume 33, 1882, were published in Philadelphia. This series was continued as the *Journal*, which, beginning in July, 1883, has been published in Chicago, where the headquarters of the association now are. In 1930 the membership of the American Medical Association was 98,000.

In 1888 Mr. John D. Rockefeller, in cooperation with the American Baptist Education Society, took steps looking to the establishment of a new University of Chicago, contributing \$600,000 under the stipulation that a further \$400,000 should be raised. This requirement was soon met, and in addition a suitable location valued at \$125,000 was donated by Mr. Marshall Field, so that in June, 1890, the Baptist Education Society was able to grant a charter, and in September, 1890, a board of trustees of 21 members was selected. The university was formally founded in 1892. It is privately endowed and coeducational, and non-sectarian, although of its 30 trustees 18 must be Baptists.

The original faculty consisted of 30 professors, 35 associate and assistant professors, 5 docents, 27 instructors and lecturers, 20 senior fellows, 15 junior fellows, 8 honorary fellows and 4 non-resident fellows. Among the professors were 9 former presidents of other institutions of higher learning, and 2 past presidents of the association, Thomas Chrowder Chamberlin and Albert A. Michelson. Other well-known men on the faculty in the early years were Charles O. Whitman, Jacques Loeb, Samuel W. Stratton, George E. Hale, Adolph C. Miller and Edward W. Bemis. Two members of the faculty have received the Nobel prize in physics, Robert Andrews Millikan (1896-1921) and Arthur Holly Compton (1923-).

The chief aims of the university have been research and graduate education, following the ideals set by its first president, William Rainey Harper, and expressed in its earliest organization.

The university includes 123 professors having to do with science, 64 on the faculty of arts, literature and science, 34 in the Rush Medical College and 25 on the faculty of medicine in the Ogden School of Science.

That a university press should form

an integral part of the University of Chicago was planned from the beginning, and the University of Chicago Press, patterned more or less after the Oxford University Press in England, was the first university press to be established in America. In the 40 years of its existence the output of the University of Chicago Press has grown from 6 books to more than 900 books and 15 scholarly journals. During its fiscal year 1931-32 no less than 116 books were published.

In October, 1892, after consultation with Professor George E. Hale and President Harper, of the University of Chicago, Mr. Charles T. Yerkes gave the order for the forty-inch lens, then unfinished, in the possession of Alvan Clark, of Cambridge, Mass., and for an equatorial mounting for it to be constructed by Messrs. Warner and Swasey. The mounting was prominent among the exhibits at the World's Columbian Exposition in 1893. The operations of building, mounting and adjusting were completed in October, 1897, when the work of the new observatory was formally inaugurated by a well-attended congress of leading astronomers.

The Field Museum of Natural History was established in 1893 at the close of the World's Columbian Exposition by a gift of \$1,000,000 from Marshall Field. It was opened in the former Palace of Art of the exposition with material obtained by gift and purchase at the exposition. In 1908 the founder bequeathed a further \$8,000,000, half for a building fund and half for endowment. The present building was opened in 1921.

The John Crerar Library was incorporated on October 12, 1894, and organized on January 12, 1895. This is a free public reference library of scientific and technical literature, its special field being the natural, physical and social sciences and their application. The administration of the library is not organized into

departments, except in regard to the medical sciences. When the Chicago Public Library was established, shortly after the great fire in 1871, it received as a nucleus for a medical library the collections of the Chicago Medical Society, the Medical Press Association and the Homeopathic Relief Association, with the understanding that the city would build up a medical reference collection. But the Public Library did not have sufficient space for the purpose, and its directors doubted if it came within its proper scope. The Medical Library Association of Chicago was then incorporated to do the work, but the expense proved to be too great for its resources, and the trustees of the Newberry Library were asked to accept as a gift the collection already made, and to carry on the work. In August, 1907, the books were transferred to the John Crerar Library, together with the library of Dr. Nicholas Senn, including the notable surgical library of Dr. Wilhelm Baum, of Göttingen, the physiological library of Dr. Emil Du Bois-Reymond, of Berlin, and a general collection made by the book dealer, E. Geibel, of Hanover. The medical department of this library ranks well among the medical libraries of the world.

The American Association for the Advancement of Science met in Chicago for the second time from December 30, 1907, to January 4, 1908. This was its fifty-eighth meeting. The number of members officially registered at this meeting was 725. Members of affiliated societies who were not members of the association registered to the number of 185. The total membership at that time was 4,727.

At the second Chicago meeting a letter was received from President Theodore Roosevelt, dated December 31, 1907, enclosing a copy of a letter which on November 11 he had addressed to the governors of each of the several states

relative to a proper conservation of the natural resources of the country, and inviting the governors, with their experts, to meet in conference on this subject at the White House in Washington from May 13 to 15, 1908. The President invited the cooperation of the association in properly bringing this matter before the public, and also invited the president of the association to take part in the conference.

The seventy-third meeting of the association, the third Chicago meeting, was held from December 27, 1920, to January 1, 1921.

The Museum of Science and Industry was established in 1926. It was founded by Julius Rosenwald with a gift of \$3,000,000 for equipment and the preparation of collections and exhibits. The original name—Rosenwald Industrial Museum—was changed in 1929. Building was begun in 1929 with the proceeds of a \$5,000,000 bond issue authorized by the South Park Commissioners. The building is a reconstruction in stone of the Fine Arts Building of the 1892 World's Columbian Exposition.

The Adler Planetarium and Astronomical Museum was presented to the South Park Commissioners by Max Adler in 1930. It is situated on an artificial island in Lake Michigan, which was built by the commissioners.

In this country memorials to scientific men outside of academic institutions are rather rare. It is of interest, therefore, to recall the excellent bronze statue of Karl von Linné (Linnaeus) in Lincoln Park, which was the gift of the Scandinavian citizens of Chicago.

This brief sketch of the history of the development of Chicago as a scientific center is only a portion of the picture as a whole. The following additional organizations are either located in Chicago, or have their headquarters there:

Hahnemann Medical College and Hospital of Chicago (established in 1855 and now affiliated

with Valparaiso University, Valparaiso, Indiana).

Chicago Historical Society (1856).

Chicago College of Pharmacy (established in 1859; in 1896 it became the School of Pharmacy of the University of Illinois).

American Veterinary Medical Association (1863).

Chicago Dental Society (1864).

American Association of Engineers (1869).

American Library Association (founded in Philadelphia in 1876).

Chicago Pathological Society (1878).

The Art Institute of Chicago (1879).

Illinois Pharmaceutical Association (1880).

National Association of Power Engineers (1882).

American Surgical Association (organized in 1880 in Philadelphia).

American Association of Railway Surgeons (1888).

Association of American Medical Colleges (1891).

American Railway Bridge and Building Association (1891).

American Numismatic Association (1891).

Armour Institute of Technology (1892; there are 8 professors of scientific subjects).

Walker Museum of Paleontology (1893).

William Webb Museum of Northwestern University Dental School (1896).

Geographic Society of Chicago (1898).

American Railway Engineering Association (1899).

Frederick Robert Zeit Museum of Pathology of Northwestern University (1899).

American Philosophical Association (1900).

German-American Historical Society of Illinois (1900).

Classical Museum of the University of Chicago (1900).

College of Dentistry of the University of Illinois (1901).

The Central Association of Science and Mathematics Teachers, Inc. (1902).

John Rockefeller McCormick Memorial Institute for Infectious Diseases (1902).

Chicago Urological Society (1903).

National Association Boards of Pharmacy (1904).

American Sociological Society (1905).

Chicago Tuberculosis Institute (1906).

Swedish Engineers' Society (1908).

Illinois Society for Mental Hygiene (1909).

Society of Medical History of Chicago (1909).

Abbott Laboratories (1910).

American Institute of Refrigeration (1910).

Nelson Morris Institute for Medical Research (founded as part of the Michael Reese Hospital).

Federation of American Societies of Experimental Biology (1913).
American College of Surgeons (1913).
Eugenics Education Society (1914).
American Association of Industrial Physicians and Surgeons (1915).
Chicago Society of Internal Medicine (1915).
Institute of Medicine of Chicago (1915).
Central States Pediatric Society (1915).
Clay Products Association (1916).
Research Laboratory of the Portland Cement Association (1916).
Society of Industrial Engineers (1917).
American Bronchoscopic Society (1917).
Oriental Institute of the University of Chicago (1919).
National Dairy Council (1919).
Electric Steel Founders' Research Group (1920).
American Specifications Institute (1921).
American Physiotherapy Association (1921).
American Congress of Physical Therapy (1922).
National Conference on Pharmaceutical Research (1922).
Acoustical Society of America (1929).

In addition to these, there are the following:

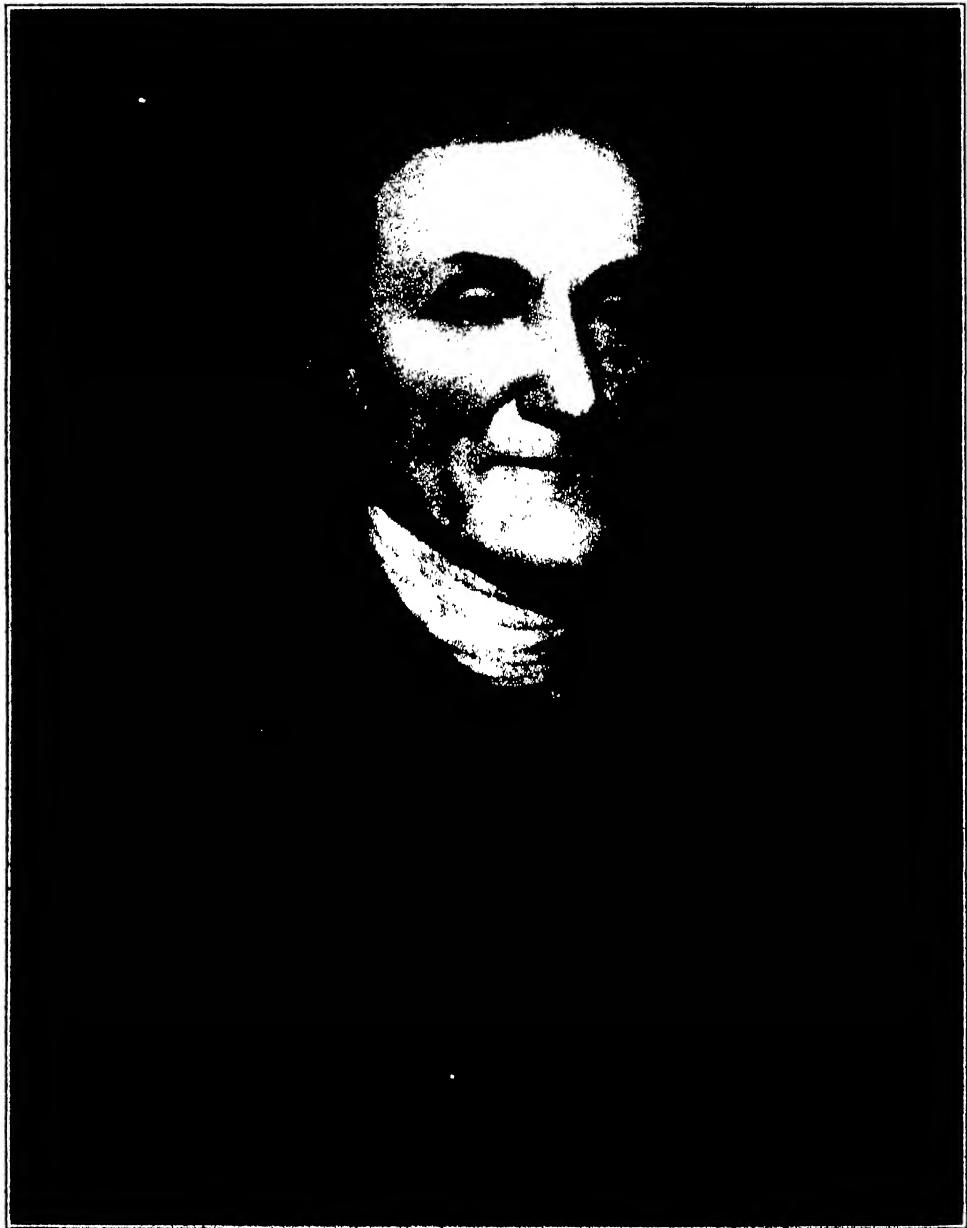
Radiological Society of North America.
American Board for Ophthalmic Examinations.
Public Health Institute of Chicago.
American Dental Association (with 35,000 members).
American Dietetic Association.

Illinois Audubon Society.
American Hospital Association.
Northwestern University Museum of the College of Liberal Arts.
Natural History Museum of the Loyola University.
The Museum of the Presbyterian Theological Seminary.

There are 28 libraries in Chicago in addition to those connected with institutions.

As a scientific center Chicago is unique among the cities of the world. Here the scientific spirit has grown up in an atmosphere of endemic curiosity. It was for the most part a local development having its origin in the inquiring minds of energetic and intellectual people who had more or less completely broken away from the old traditions. So it has grown up more largely along economic and practical than along cultural lines. The possibilities of applying science for the benefit of all have taken precedence over the cultural aspects. But at the same time the cultural side of science has by no means been neglected.

In no other city is science, from our American view-point and in harmony with our American spirit and ideals, more highly developed than in Chicago.



THE STUART PORTRAIT OF JOSEPH PRIESTLEY

THE PROGRESS OF SCIENCE

JOSEPH PRIESTLEY¹

THE numerous exercises held in commemoration of the bicentenary of the birth (March 13, old style, 1733) of Joseph Priestley by colleges, universities and various religious organizations, both in this country and abroad, testify to the interest in the work and the appreciation of the influence of this remarkable man. Best known for his work in theology and science, he made his influence felt also in the fields of politics, sociology, philanthropy, history, philosophy and education.

In religion Priestley was a dissenter and in his time in England these beliefs were very unpopular. Along political lines his democratic ideas were far in advance of his period and equally unpopular. While calm and dispassionate in the manner in which he expressed his views he nevertheless was unequivocal and persistent. His constant repetition of his beliefs irritated his opponents. It has been said that he "acquired the reputation of being the most cantankerous man of his time . . ." This antagonism culminated in the riots in Birmingham in 1791 and carried with it so much of persecution and discomfort that he emigrated to America. Not every one was against him. His close friends were ardent supporters and would have had him remain. Even among the opponents of his political and religious beliefs there were many who regretted his entry into controversial discussions and who hoped that he might spend all his energy in philosophical pursuits.

Priestley and his wife sailed for America on April 8, 1794, and after a tiresome voyage of nearly two months

¹ In the preparation of this note on Priestley, the writer has drawn freely on articles by Dr. C. A. Browne, Dr. Lyman C. Newell and the late Dr. Edgar Fahs Smith.

arrived in New York on June 4. They were met by their son Joseph and his wife, who were already established at Northumberland, Pennsylvania. After being cordially entertained in New York and in Philadelphia, as they passed through, the party arrived at Northumberland about August 1. Here, except for short visits to Philadelphia, Priestley lived until his death, on February 6, 1804.

Priestley's fame as a clergyman and as a scientist had preceded him to America. On his arrival in New York he was visited by Governor Clinton, Dr. Prevost, bishop of New York, the principal merchants and by deputations from political, educational and scientific organizations bringing messages of welcome. To most of these Priestley found time to make appropriate response. The *American Daily Advertiser* of that time paid the following tribute to him, in an editorial: "The name of Joseph Priestley will be long remembered among all enlightened people; and there is no doubt that England will one day regret her ungrateful treatment to this venerable and illustrious man."

Priestley's replies to the messages of welcome were free from rancor but were quite frank with respect to the treatment accorded him in England. And as always he expressed freely his own views on religious and political subjects. Not long after the publication of these addresses and his replies he became the subject of an attack by William Cobbett, an Englishman, who wrote under the pen-name of Peter Porcupine. Priestley was much annoyed by this writer, whose attacks continued periodically until the latter returned to England in 1800. During the remainder of his life, Priestley was occasionally disturbed by similar



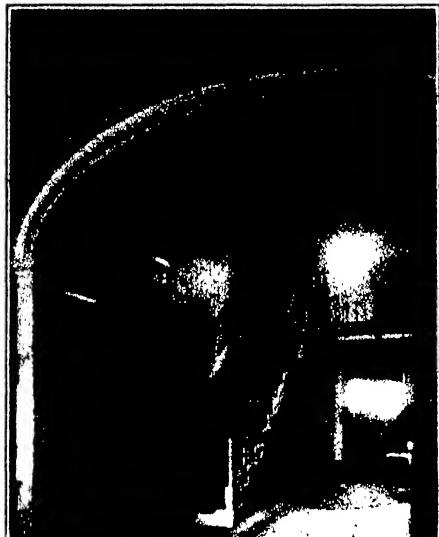
PRIESTLEY'S HOME AT NORTHUMBERLAND, PA.
VIEW FROM THE SOUTHWEST SHOWING THE PRIESTLEY MUSEUM.
(OWNED BY THE PENNSYLVANIA STATE COLLEGE.)

charges of a biased and unfair nature. Meanwhile, the better publications were coming to his support and thoughtful men of the country who admired his fair attitude on all controversial questions and who appreciated his achievements in science were paying him increased honor and respect.

With all his many interests Priestley was first of all a minister—a theologian. He was ordained while at Warrington. The preparation of his articles on religious subjects claimed much of his time up to the very end. His writings in this field and on related subjects are voluminous and are sufficient in themselves to earn for him a place of honor. The last ten years of his life, which were spent at Northumberland, were not unfruitful. Here were completed his "Church History," his "Notes on the Scriptures," "Socrates and Jesus Compared" and his "Comparison of the Institutions of Moses with those of the Hindoos." On his visits to Philadelphia, he was delighted to occupy the pulpit when opportunity offered. Here

he established the first Unitarian church in America.

In educational matters Priestley always maintained a live interest. For a time in England he was a teacher at Warrington Academy. At Northumberland he gathered a class of fourteen young men who had adopted his Unitarian ideas, to whom he lectured on theology and philosophy. He was offered the professorship of chemistry at the University of Pennsylvania, but declined it, influenced in this action by the state of his health and the difficulty of removing his books and apparatus to Philadelphia, and also by the expectation that in a year or two a college would be established at Northumberland. His interest in education, his accomplishments in science and his liberal views on politics brought about a close friendship with Thomas Jefferson. He was frequently consulted by Jefferson with regard to plans for a university which the latter was proposing to establish in Virginia. In the "Hints Concerning Public Instruction" which he



MAIN HALLWAY OF THE PRIESTLEY HOUSE

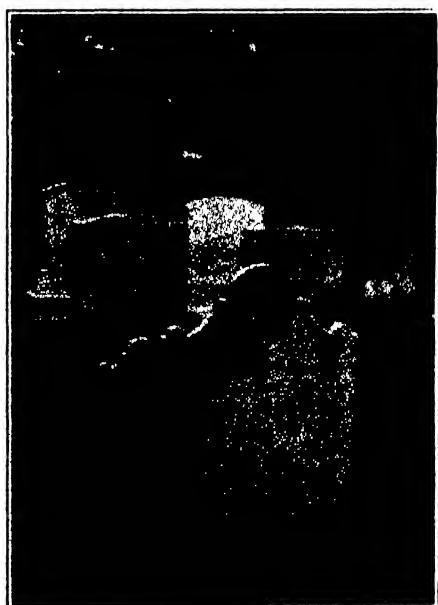
prepared for Jefferson are expressed many views on education which would be considered modern to-day. The establishment of an academy at Northumberland in which he would feel free to impart his Unitarian doctrines was a fond but unfulfilled hope.

To Priestley science was an avocation, which is no reflection on his interest or his achievements in that field, rather the contrary. His attention was only turned to chemistry when in his thirties, by Dr. Matthew Turner, of Liverpool, who lectured on the subject at Warrington Academy while Priestley was a teacher there. His interest in science was further stimulated by Benjamin Franklin, whose acquaintance he made on one of Franklin's visits to London. While living in Leeds his home adjoined a public brew house. He was led to amuse himself by making experiments on carbon dioxide (fixed air) which is produced in the fermentation process. With very little funds at his command and with no background in science he was under the necessity of devising both apparatus and method of attack.

His first paper on "Pneumatic Chemistry," the results of his experiments at Leeds, was published in 1772. It was immediately translated into French and attracted a great deal of attention to the subject. For this paper on soda-water he received in 1773 the Copley Medal.

In 1774 came the discovery for which he is best known—that of oxygen. With but two years in science it was rare good fortune. That it was not wholly accidental is evidenced by the long series of gases that Priestley discovered. Oxygen, ammonia, hydrogen chloride, hydrogen sulfide, sulfur dioxide, nitric oxide, nitrous oxide and carbon monoxide comprise the list. It is an imposing list and fixes for all time Priestley's place in chemistry.

Soon after his arrival in Northumberland, Priestley made plans for a house and a laboratory. For a time he had only one room in his son's house for his library and apparatus and this was so cold that it was impossible for him to work in winter. His most important



PRIESTLEY'S GRAVE AT NORTHUMBERLAND, PA.

discovery in the investigations made at Northumberland was that of carbon monoxide, which he obtained in 1799 in several ways. Other investigations include spontaneous combustion, diffusion of gases, the liberation of air from water and the action of caustic alkalies on flint glass. His dominating purpose at this time was to overthrow the French school of chemistry proposed by Lavoisier. During these years he finished his last scientific work, "Doctrine of Phlogiston Established."

Priestley would never accept the simpler French view. The results of his experiments were susceptible of two interpretations and were frequently used to support the views of his opponents. His experiments were admirably done,

but he failed in the interpretation of their theoretical relations. It has been said of him—"In theory he had no instinct for guessing right . . . he may almost be said to have had a predilection for the wrong end."

Priestley's coming to America aroused a live interest in chemistry which has in no sense diminished since his time. His library and laboratory at Northumberland were among the best equipped of his time. He appeals strongly because of the persistency of his efforts in research. The influence of his accomplishments can hardly be overestimated.

G. C. CHANDLER

DEPARTMENT OF CHEMISTRY

PENNSYLVANIA STATE COLLEGE

THE ANNUAL MEETING OF THE NATIONAL ACADEMY OF SCIENCES

THE National Academy of Sciences has reached the age of threescore years and ten. This is, however, not an old age for a scientific society; the Accademia Nazionale dei Lincei at Rome was founded in 1603, The Royal Society in 1645, The Prussian Academy in 1700, and The American Philosophical Society in 1727. The National Academy of Sciences was incorporated by Act of Congress on March 3, 1863, and held its first meeting in New York City on April 22, 1863, for organization purposes only. Its first meeting with scientific sessions was held in Washington from January 4 to 9, 1864; since then it has held, each year, an annual meeting in Washington and has devoted the greater part of the meeting to sessions for the presentation and discussion of scientific papers. At the recent meeting from April 24 to 26 in Washington, at the Academy building, sixty-six papers were read from the following fields of science: Mathematics, 2; astronomy, 7; physics, 16; chemistry, 3; geology, 2; paleontology, 2; oceanography, 1; meteorology, 2; botany, 2;

biochemistry, 1; biophysics, 2; physiology, 14; embryology, 1; genetics and evolution, 5; pathology, 1; psychology, 3; anthropology, 2. Of these papers 45 were given by members of the academy, 5 by invited guests and 16 by scientists introduced by members. Two sessions were held each morning and afternoon on Monday and Tuesday. The average attendance at the sessions was 450; the papers were unusually interesting and were freely discussed. On Monday evening Dr. Thomas Hunt Morgan, former president of the academy, delivered a public lecture on "The Bearing of Genetics on the Theory of Evolution" to an appreciative audience of six hundred.

One of the most important communications was the address given at the annual dinner on Tuesday evening, by the president of the National Academy of Sciences, on the status of research in science in this country. President Campbell emphasized the importance of research and the need for its continuance. To quote from his address:



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PROFESSOR OF PURE MATHEMATICS,
RICE INSTITUTE.



DR. J. F. RITT
PROFESSOR OF MATHEMATICS,
COLUMBIA UNIVERSITY.



DR. S. A. MITCHELL
DIRECTOR, LEANDER McCORMICK OBSERVATORY,
UNIVERSITY OF VIRGINIA.



HAROLD D. BABCOCK
PHYSICIST, MOUNT WILSON OBSERVATORY.



BANCROFT GHERARDI

VICE PRESIDENT, AMERICAN TELEPHONE AND
TELEGRAPH COMPANY, NEW YORK CITY.



DR. HERBERT E. IVES
PHYSICIST, BELL TELEPHONE LABORATORIES.

In my opinion, the products of research and invention in the domain of the physical and biological sciences have been more potent in advancing the state of civilization on the earth from its low level of the fifteenth century to its high level of the twentieth century than have all other forces combined. I do not expect universal acceptance of this thesis, but I am prepared to defend it. There is no question that many other forces, both idealistic and practical, have been exceedingly influential and powerful in behalf of the nations and their peoples, but in the main those forces would not have existed, or certainly could not have oper-



DR. LINUS PAULING
PROFESSOR OF CHEMISTRY, CALIFORNIA INSTITUTE
OF TECHNOLOGY.

ated, if the physical and biological sciences had not provided the mental and moral attitudes, the opportunities, the *open sesame* that permitted them to go out into the great world and exert their effective and beneficent influences.

I have been speaking of research activities and research results of the present and of the recent past; but what of the future, even of the immediate future? They threaten to be very different. A condition of intense anxiety on this subject exists in nearly all our universities, in the research institutions, in the learned societies in general, in the research organiza-

tions supported by the Government of the Nation, and with countless thousands of public-spirited and wide-awake citizens who have a fair comprehension of what scientific discovery, through experimentation and research, have done for humanity. In many universities, especially state universities, where research, sympathetically nurtured and supported through the years, has brought forth new knowledge of tremendous importance to the welfare of the nation, the degree of existing anxiety as to what may happen can be said to have approached, here and there, the stage of fear. The legislatures of the majority of our states are now in session, and they have the duty of appropriating funds for the support of their respective educational institutions through the



DR. H. C. SHERMAN
MITCHELL PROFESSOR OF CHEMISTRY,
COLUMBIA UNIVERSITY.

next two years. The attitude of many, perhaps all the legislatures toward research at public expense may fairly be described as unsympathetic and, in some cases, I am informed, as severely hostile. I need not say to this audience that a university, shorn of its research activities and deprived of the scholarly atmosphere that research develops, will eventually differ but little in character from what we might call a *higher high school*. The name "university" will remain, but the qualities special to a real university will dwindle and disappear. The Book of Great Wisdom, tried



DR. THOMAS BARROUR
DIRECTOR, MUSEUM OF COMPARATIVE ZOOLOGY,
HARVARD UNIVERSITY.



DR. BERNARD O. DODGE
PLANT PATHOLOGIST, NEW YORK
BOTANICAL GARDEN.

and proved through the centuries, says that "Where there is no vision, the people perish." Equal confidence may be placed in the thesis, "Where there is no research, the universities perish." The governments, the universities and the peoples in Europe and in many other parts of the world understand this principle perfectly. The universities in those countries, with few exceptions, are national, or state, or municipal universities, financially supported in major degree by their governments.

Five medals were awarded at the annual dinner:

The Alexander Agassiz Medal for Oceanography, awarded to Albert Defant, of the Institut für Meereskunde, Berlin, Germany, for his studies on atmospheric and oceanic circulation and his notable contributions to theoretical oceanography. The presentation speech was made by Dr. Henry B. Bigelow, of the Woods Hole Oceanographic Institution. The medal was accepted by His Excellency, the German Ambassador, on behalf of Dr. Defant.

The Public Welfare Medal of the Marcellus Hartley Fund—for eminence in the application of science to the public welfare—was awarded to William Hallock Park, of New York City, for his work as head of the research laborato-



DR. A. R. DOCHEZ

PROFESSOR OF MEDICINE, COLUMBIA UNIVERSITY.

ries of the New York City Department of Health and as a pioneer and leader both in research and in the application of scientific discovery to the prevention of disease. The presentation speech was made by Dr. Simon Flexner, of the Rockefeller Institute for Medical Research.

The John J. Carty Medal and Award for the Advancement of Science was awarded a year ago to John J. Carty, a member of the academy, in whose honor the medal was established for his distinguished accomplishments in the field of electrical engineering, particularly as they have influenced the development of electrical communication, and also his noteworthy influence on the introduction of fundamental science and of the methods of sound scientific research as an integral and powerful tool of industrial development. Dr. Carty died on December 27, 1932. The medal was received by his son, Dr. John Russell Carty. The presentation address was made by Dr. F. B. Jewett, president of the Bell Telephone Laboratories.

The Henry Draper Medal was awarded to V. M. Slipher, a member of the academy, at Lowell Observatory, Flagstaff, Arizona, in recognition of his spectroscopic researches, among the most important of which may be mentioned: (1) The discovery of "stationary"



DR. OSWALD T. AVERY

MEMBER, ROCKEFELLER INSTITUTE FOR
MEDICAL RESEARCH.



DR. EUGENE F. DUBOIS

PROFESSOR OF MEDICINE, CORNELL UNIVERSITY
MEDICAL COLLEGE.

calcium lines in stellar spectra; (2) the development of efficient methods of observations of the spectra of spiral nebulae and the securing of the first observations of their radial velocities; (3) observations of bright lines and bands in the spectra of the night sky. The presentation address was made by Dr. H. N. Russell, of Princeton University.

The Mary Clark Thompson Medal was awarded to Francis Arthur Bather, of Wimbledon, England, for his distinguished services in the fields of paleontology and geology. His principal scientific contributions are his "Cri-
noidea of Gotland," published in Stockholm in 1893, his work on the Triassic echinoderms of Bakony in 1909, his chapters on echinoderms in Lankester's "Treatise on Zoology," and his studies on the Edrioasteroidea in 1915. The presentation address was made by Mr. E. W. Berry, of Johns Hopkins University. The medal was received on behalf of Dr. Bather by Dr. Ralph Howard Fowler, of Cambridge University, England.

At the annual business meeting the resignation of Dr. David White as vice-president, because of ill health, was accepted with regret and with expressions of appreciation of his long and faithful

services to the academy. Dr. Arthur L. Day, of the Geophysical Laboratory of the Carnegie Institution of Washington, was elected vice-president for a period of four years, beginning July 1, 1933.

Two members of the council were re-elected for a period of three years:

Dr. J. McKeen Cattell, Garrison-on-Hudson, N. Y.

Dr. Karl T. Compton, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Fourteen new members were elected:

Dr. Oswald Theodore Avery, bacteriologist, Rockefeller Institute for Medical Research, New York, N. Y.

Harold Delos Babcock, astrophysicist, Mt. Wilson Observatory of the Carnegie Institution of Washington, Pasadena, California.

Dr. Thomas Barbour, zoologist, Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts.

Dr. Alphonse Raymond Dochez, professor of medicine, Columbia University, New York, N. Y.

Dr. Bernard Ogilvie Dodge, botanist, New York Botanical Garden, New York, N. Y.



DR. W. R. MILES

PROFESSOR OF PSYCHOLOGY, YALE UNIVERSITY.

Dr. Eugene Floyd DuBois, professor of medicine, Cornell University Medical College, New York, N. Y.

Dr. Griffith Conrad Evans, mathematician, Rice Institute, Houston, Texas.

Bancroft Gherardi, electrical engineer, American Telephone and Telegraph Company, New York, N. Y.

Dr. Herbert Eugene Ives, physicist, Bell Telephone Laboratories, New York, N. Y.

Dr. Walter Richard Miles, psychologist, Yale University, New Haven, Connecticut.

Dr. Samuel Alfred Mitchell, astronomer, Leander McCormick Observatory, University, Virginia.

Dr. Linus Pauling, chemist, California Institute of Technology, Pasadena, California.

Dr. Joseph Fels Ritt, mathematician, Columbia University, New York, N. Y.

Dr. Henry Clapp Sherman, chemist, Columbia University, New York, N. Y.

In demonstration of a paper read on Tuesday morning, April 25, by Dr. F. B. Jewett on "Perfect Quality and Auditory Perspective in the Transmission and Reproduction of Music," a symphony concert, sponsored by the National Academy of Sciences, was given in Constitution Hall, Washington, D. C. The concert program was rendered by the Philadelphia Symphony Orchestra in Philadelphia; the music was transmitted by three telephone lines to Washington, where it was received and the quality of the reproduction controlled by Music Director Leopold Stokowski to give spatially-accurate and perfect-quality musical rendering, and also to increase or diminish the volume from the whole or parts of the orchestra, or to vary the volume relationship between a voice and the orchestra, thus

creating effects not heretofore attainable. On the program were included: Bach, "Toccata and Fugue in D Minor"; Beethoven, "Symphony No. 5 in C Minor"; Debussy, "L'après-midi d'un Faune"; and Wagner, Finale of "Götterdämmerung." Immediately preceding the concert President Campbell explained briefly its purpose and called attention to the fact that music was transmitted over the telephone, for the first time, 56 years ago and was sent from Philadelphia to Washington. During the intermission in the concert program, Dr. Harvey Fletcher, of the Bell Telephone Laboratories, explained and illustrated the methods by which the extraordinary effects were obtained. At the close of the concert Dr. Leopold Stokowski gave a brief analysis of the possibilities made available to musicians by the new methods which have been developed and of their influence on the development of music. Members of the academy and many others attending the concert were convinced that the demonstration marked a notable event in the history of music.

The present membership of the academy is 279, with a membership limit of 300; there are 44 foreign associates with a limit of 50. A total of 125 academy members and one foreign associate attended the meeting. The autumn meeting of the academy will be held this year in November at the Massachusetts Institute of Technology in Cambridge.

F. E. WRIGHT,
Home secretary

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